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Thorson et al.

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(54) **PIPE CUTTER**

(75) Inventors: **Troy C. Thorson**, Waukesha, WI (US);
Daniel J. Alberti, Brookfield, WI (US);
Thomas R. Bednar, Pewaukee, WI
(US); **John S. Scott**, Brookfield, WI
(US); **Scott Anderson**, Racine, WI (US)

(73) Assignee: **Milwaukee Electric Tool Corporation**,
Brookfield, WI (US)

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patent is extended or adjusted under 35
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(60) Provisional application No. 60/895,062, filed on Mar.
15, 2007, provisional application No. 60/990,862,
filed on Nov. 28, 2007.

(51) **Int. Cl.**

B23D 21/06 (2006.01)

B23Q 5/10 (2006.01)

(52) **U.S. Cl.**

USPC **30/95; 30/92; 173/11; 173/217**

(58) **Field of Classification Search**

USPC 30/95, 92, 101, 123.3, 97, 96, 93, 102,
30/500, 188, 180; 173/11, 217, 1; 82/59,
82/62, 64, 76, 77, 100, 99.1, 99.2
See application file for complete search history.

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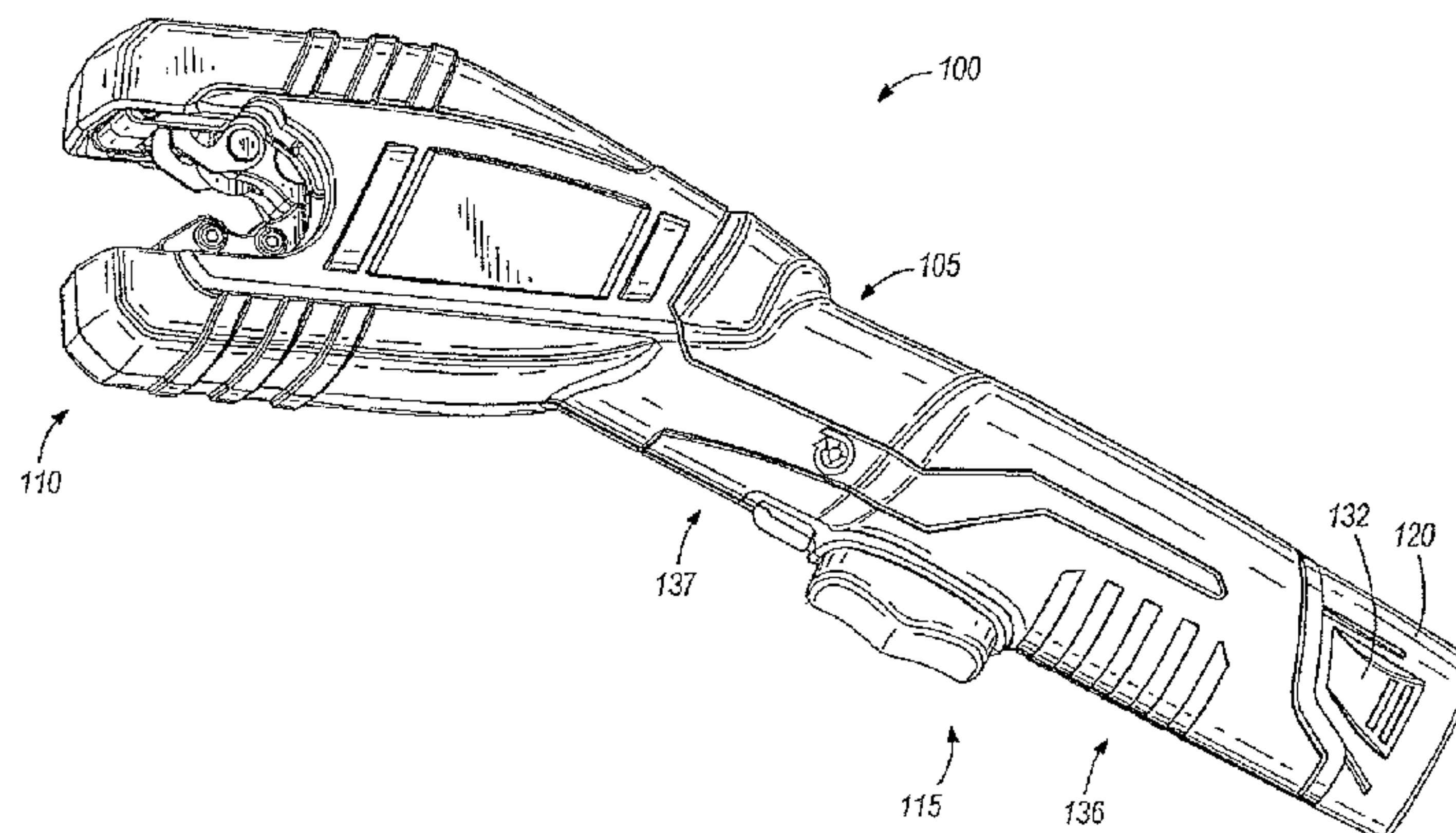
Primary Examiner — Ghassem Alie

(74) *Attorney, Agent, or Firm* — Michael Best & Friedrich
LLP

(57) **ABSTRACT**

A power tool, such as a pipe cutter, includes a rotatable
cutting head assembly, an electric motor connectable to a
rechargeable battery, and a controller. The controller is con-
figured to monitor the state of charge on the battery, compare
the state of charge to one or more thresholds, and prevent or
limit operation of the power tool when the state of charge is
less than or equal to one or more of the thresholds. In some
embodiments, the threshold includes the state of charge
required to cut a pipe, the state of charge required to return the
cutting head assembly to a home position, and a state of
charge indicative of an overdischarged condition of the bat-
tery. In some embodiments, the controller is configured to
detect when the pipe cutter has completed cutting the pipe and
returns the cutting head assembly to the home position.

14 Claims, 27 Drawing Sheets



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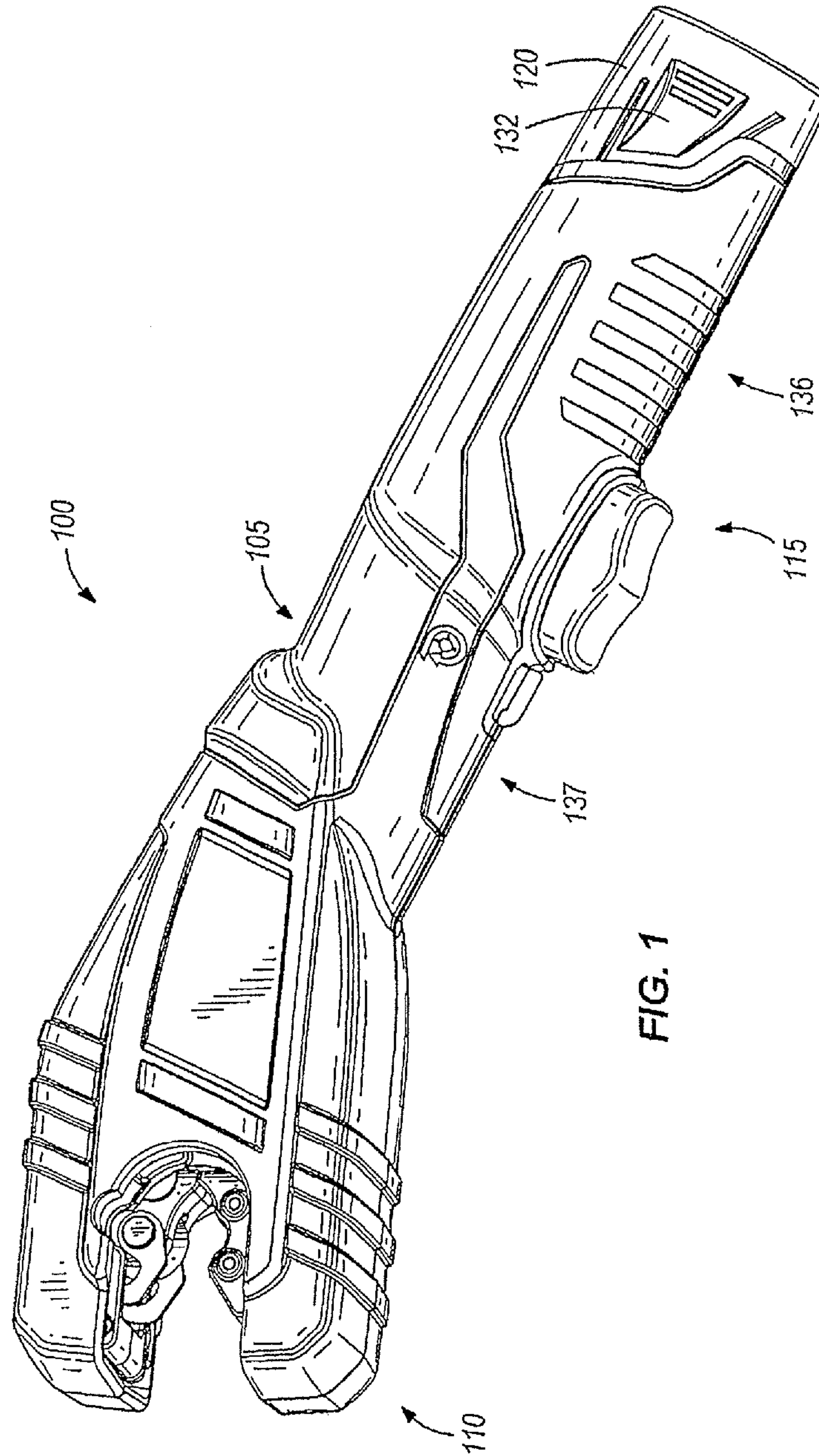


FIG. 1

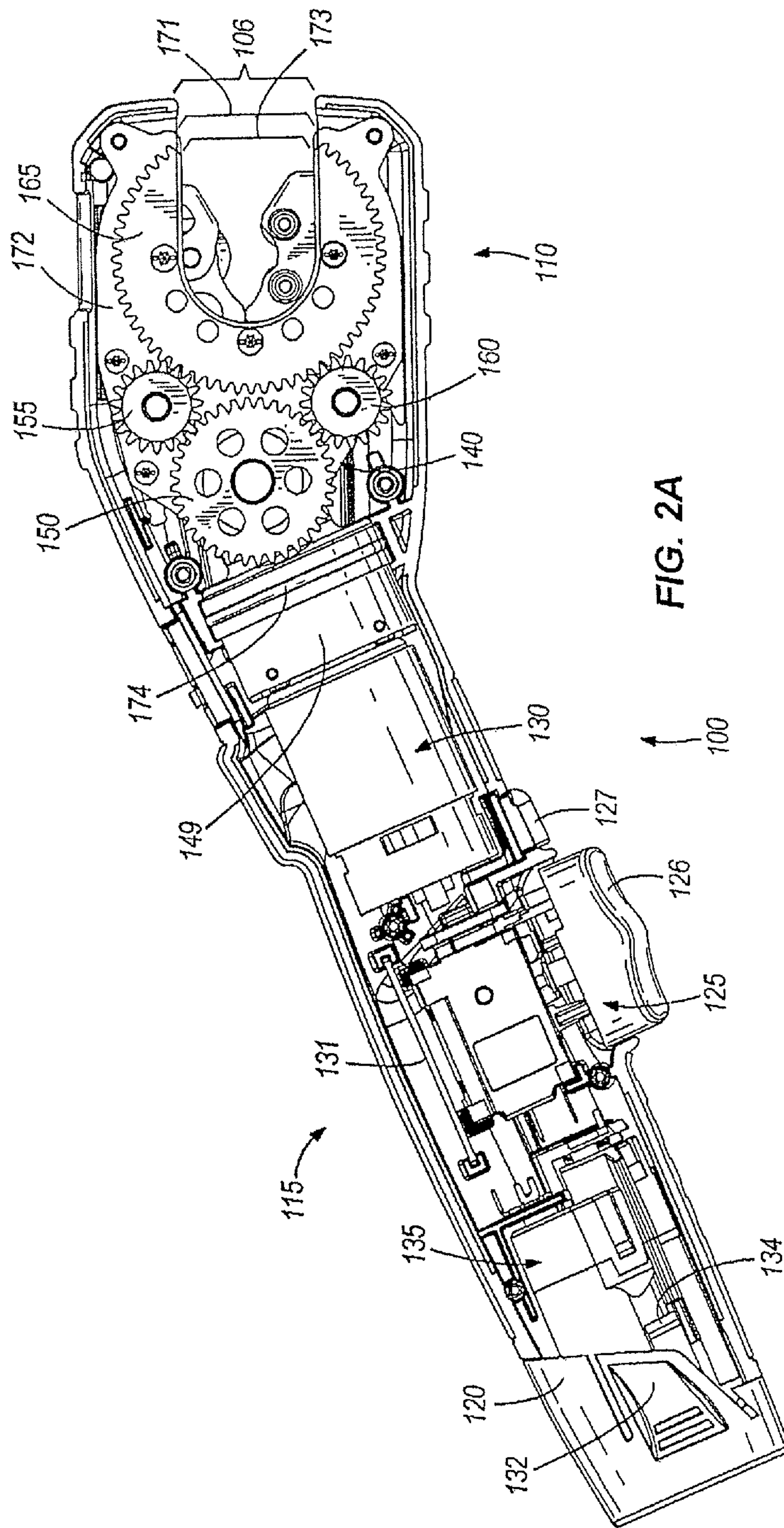


FIG. 2A

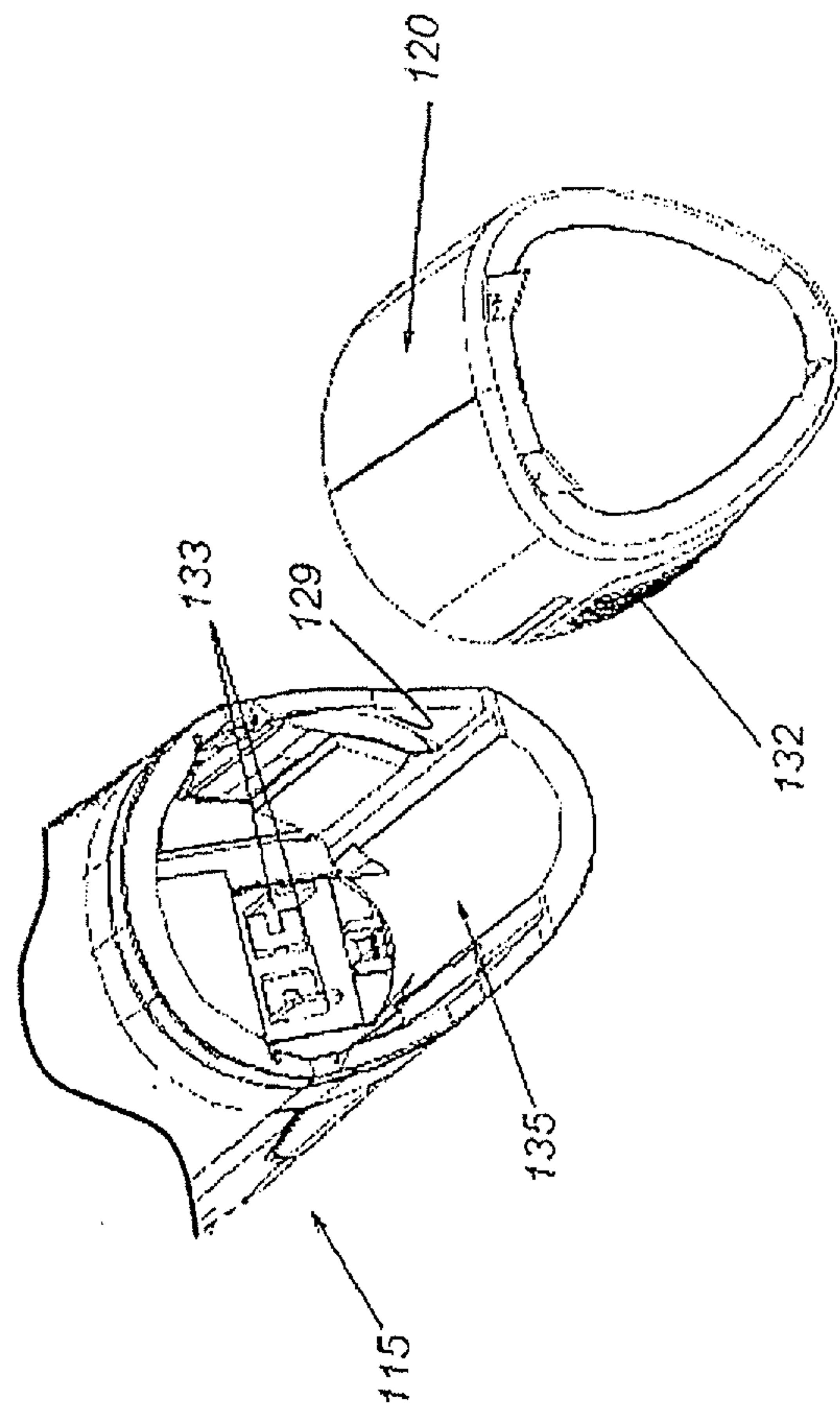


FIG. 2B

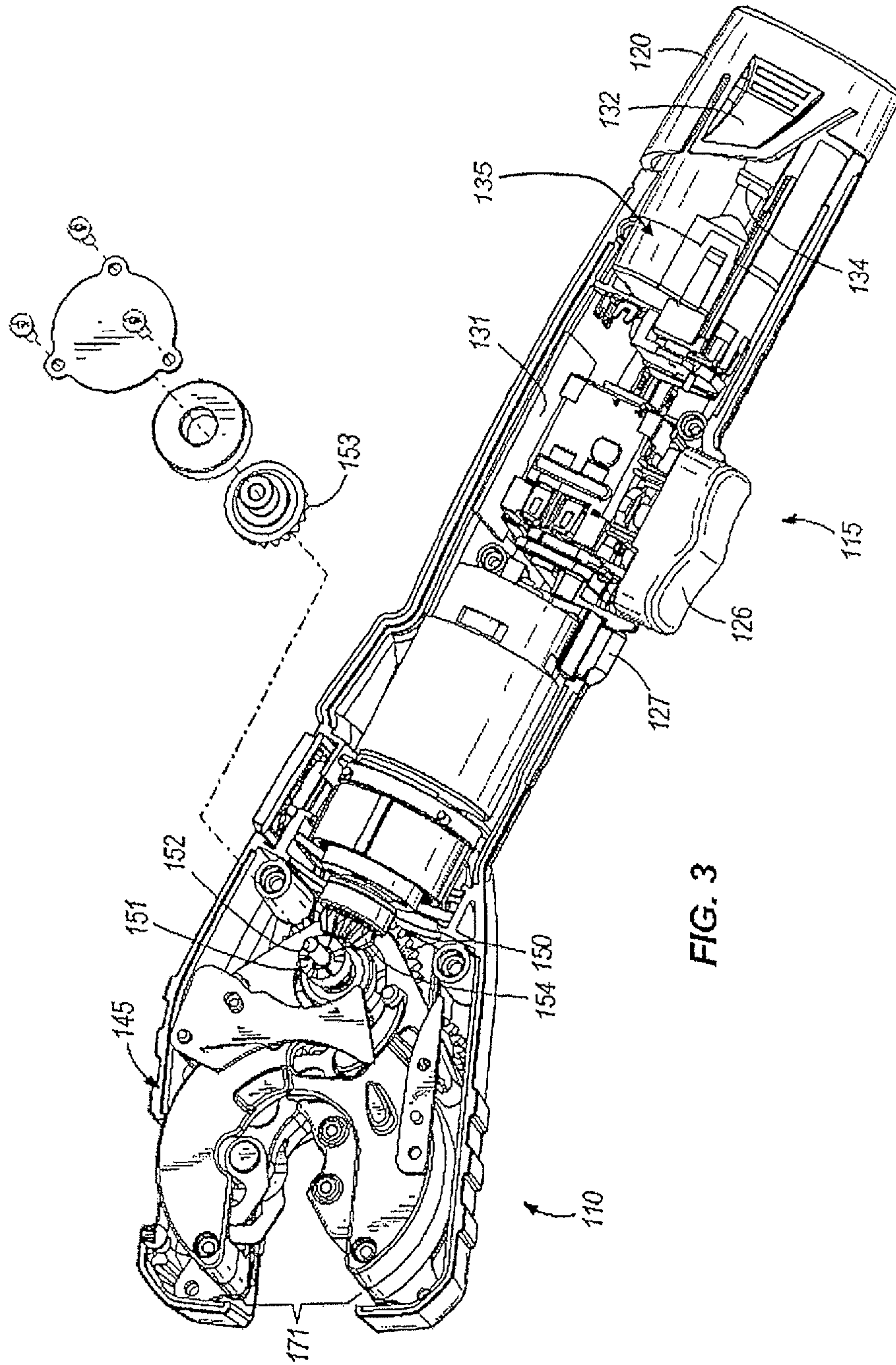


FIG. 3

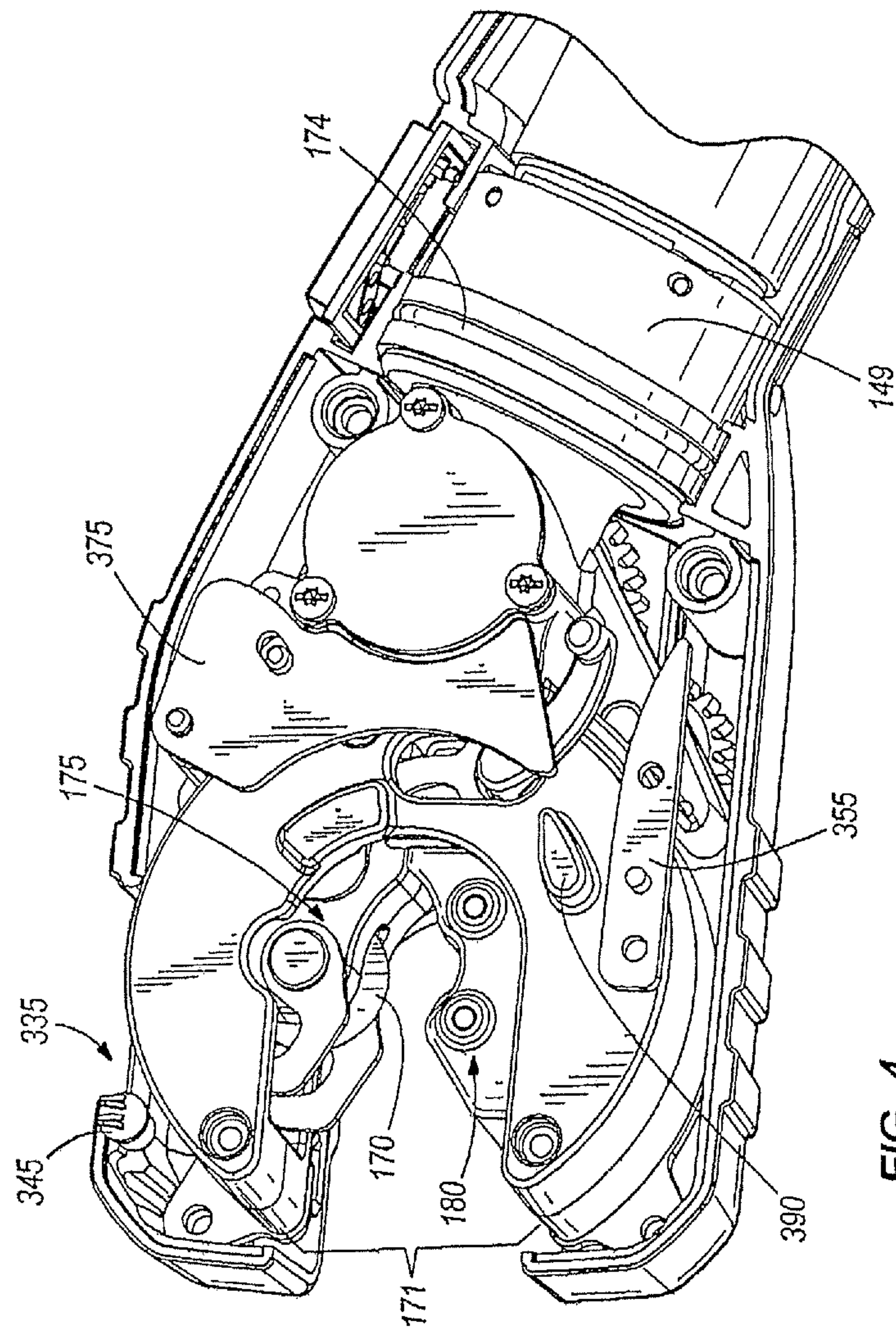


FIG. 4

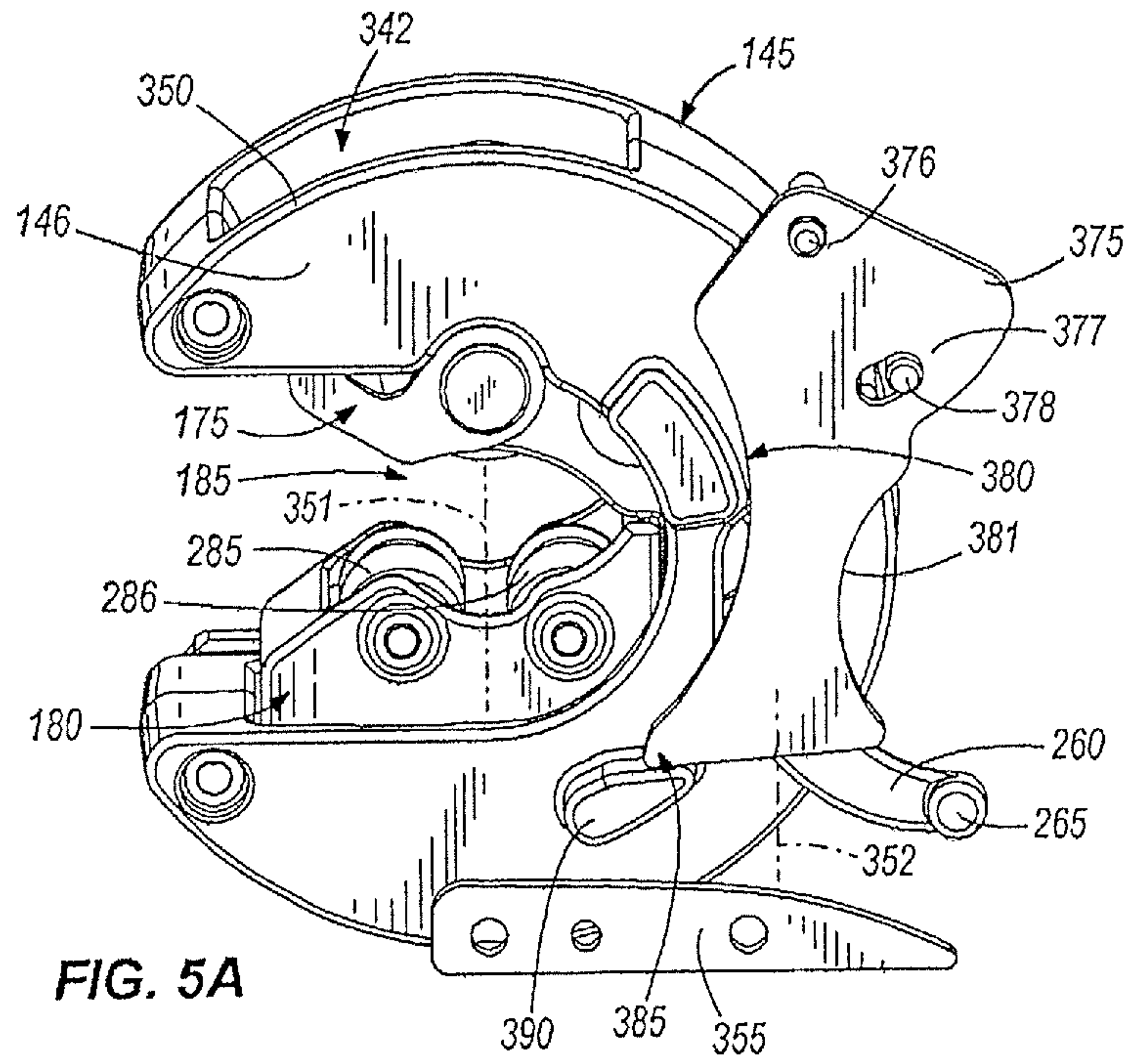


FIG. 5A

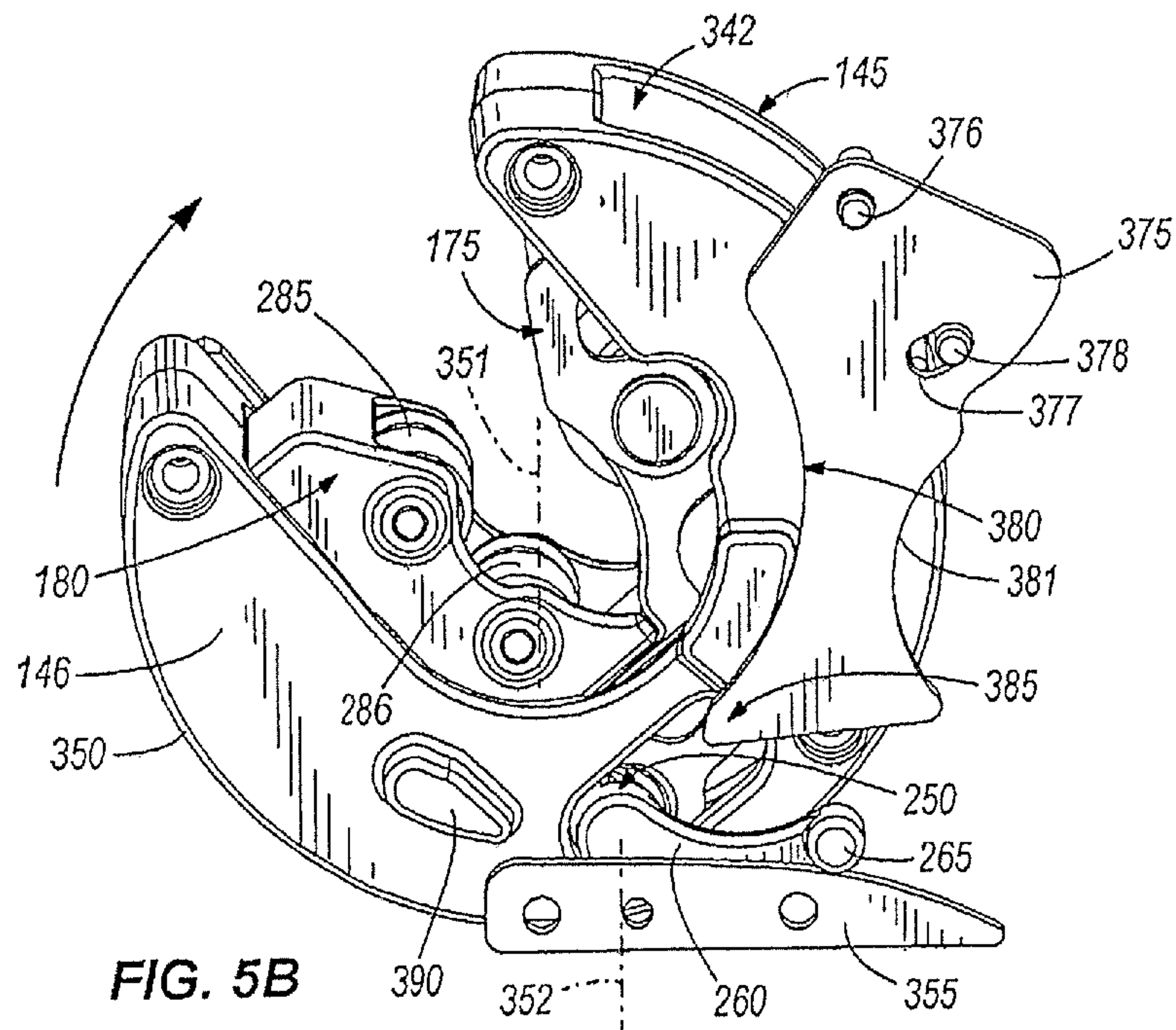


FIG. 5B

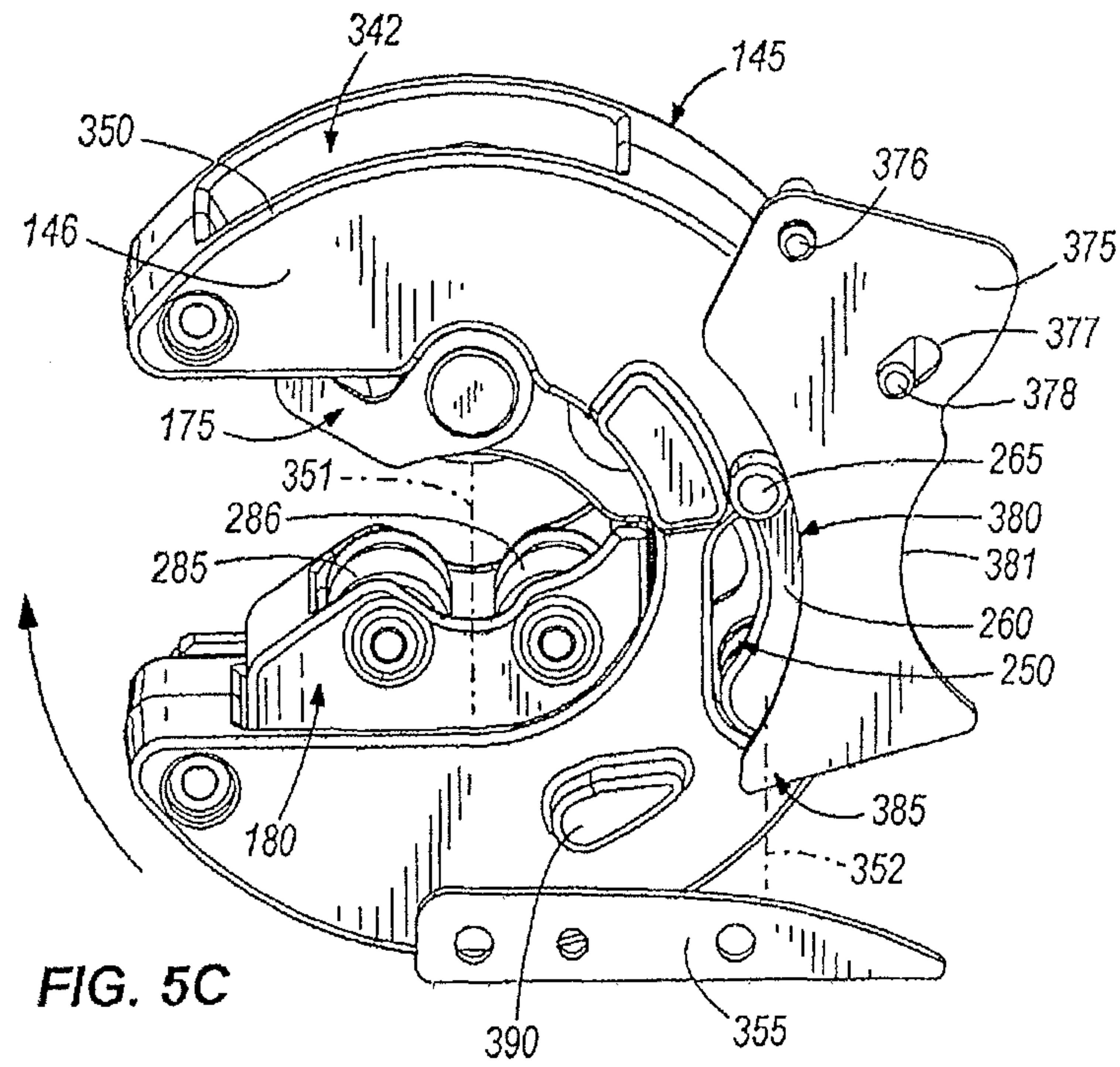


FIG. 5C

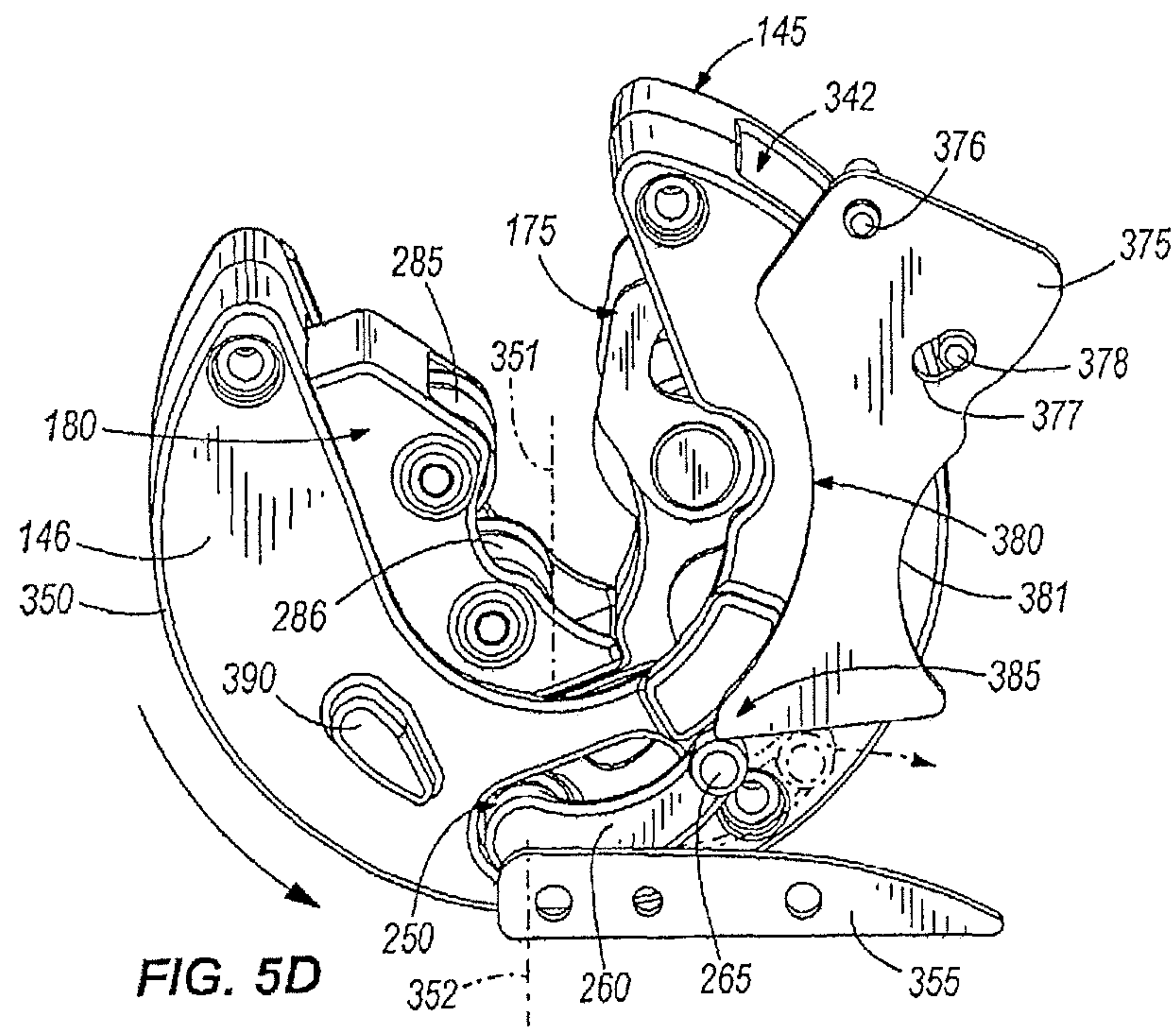


FIG. 5D

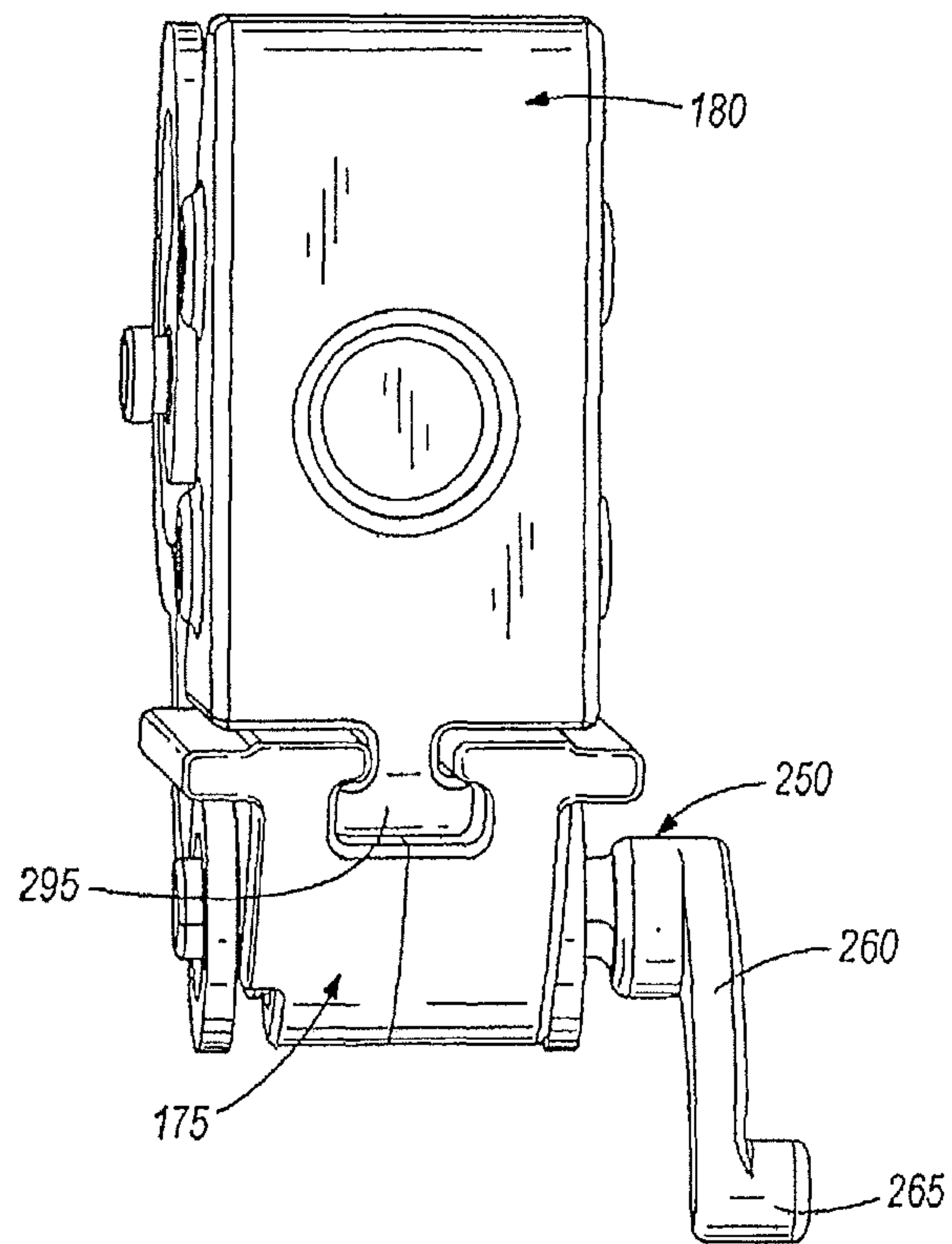


FIG. 6

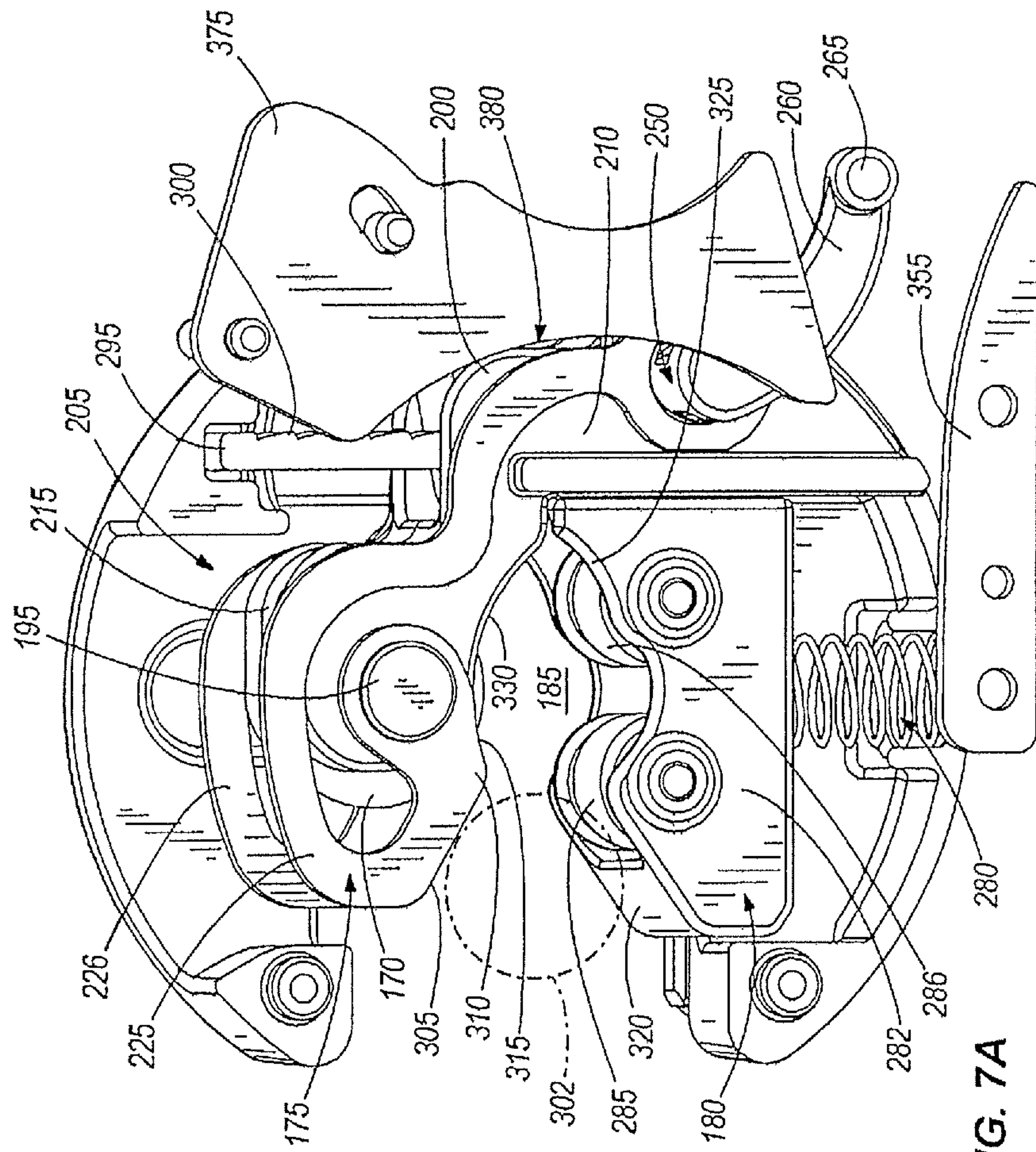


FIG. 7A

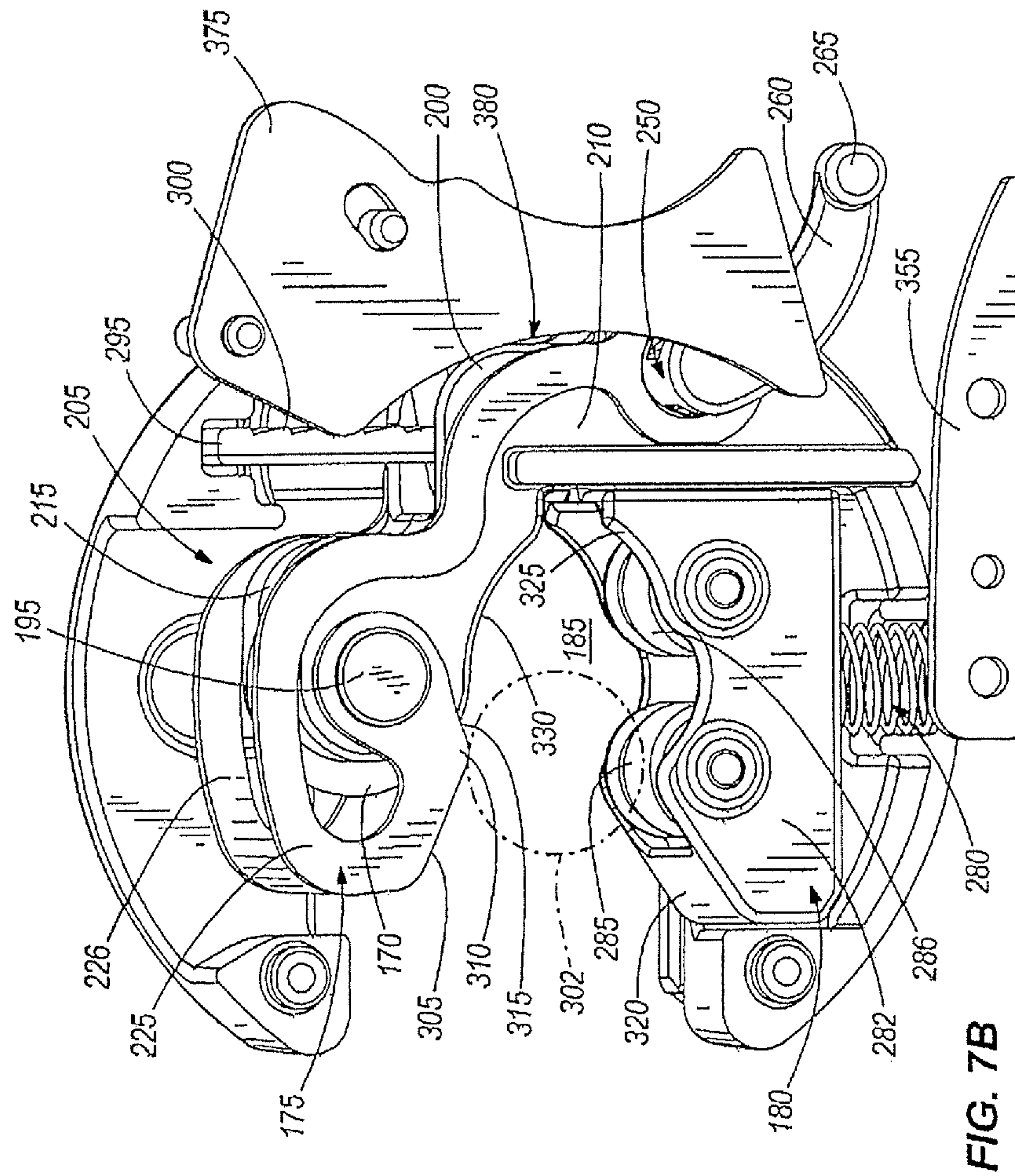


FIG. 7B

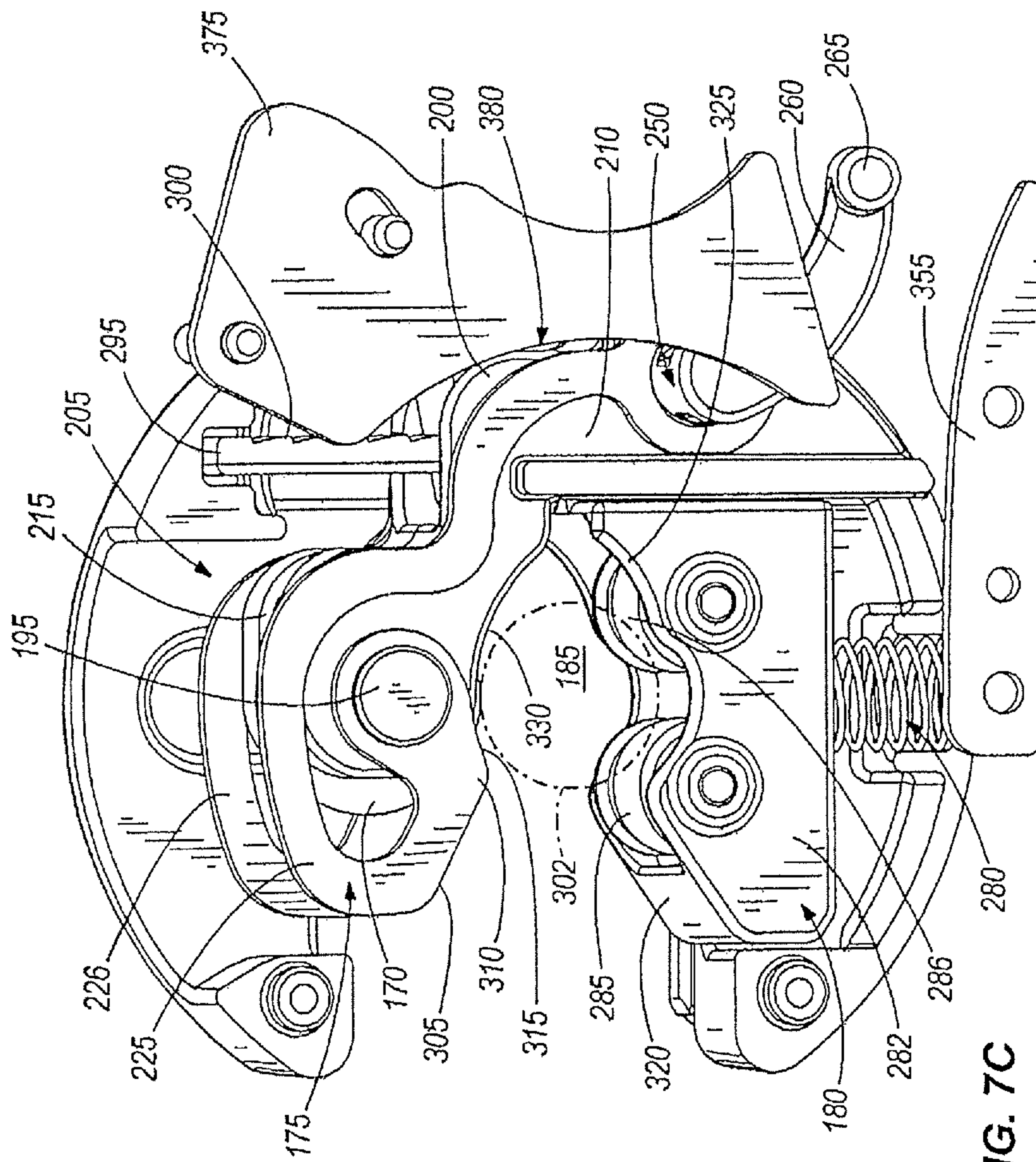


FIG. 7C

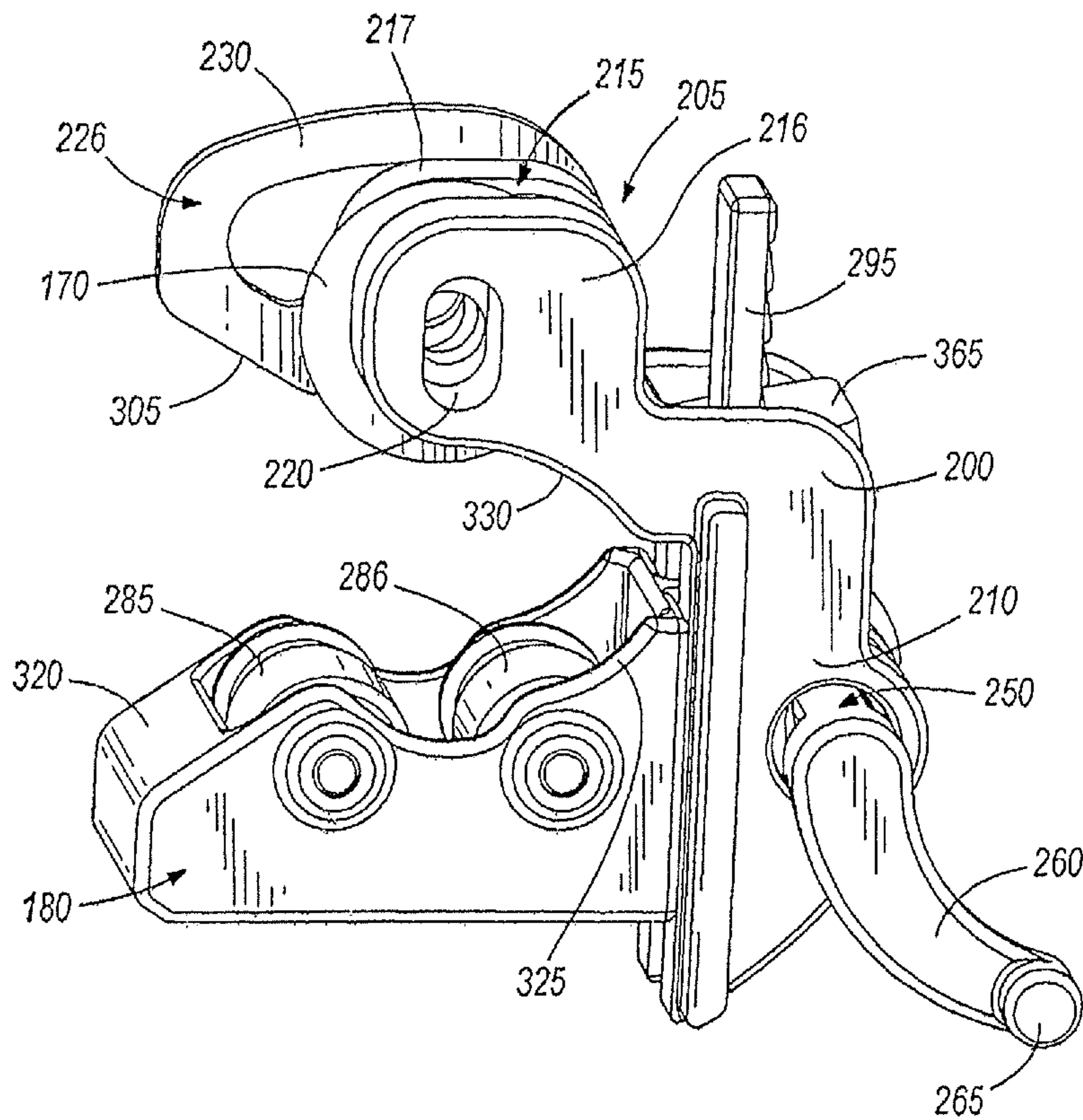
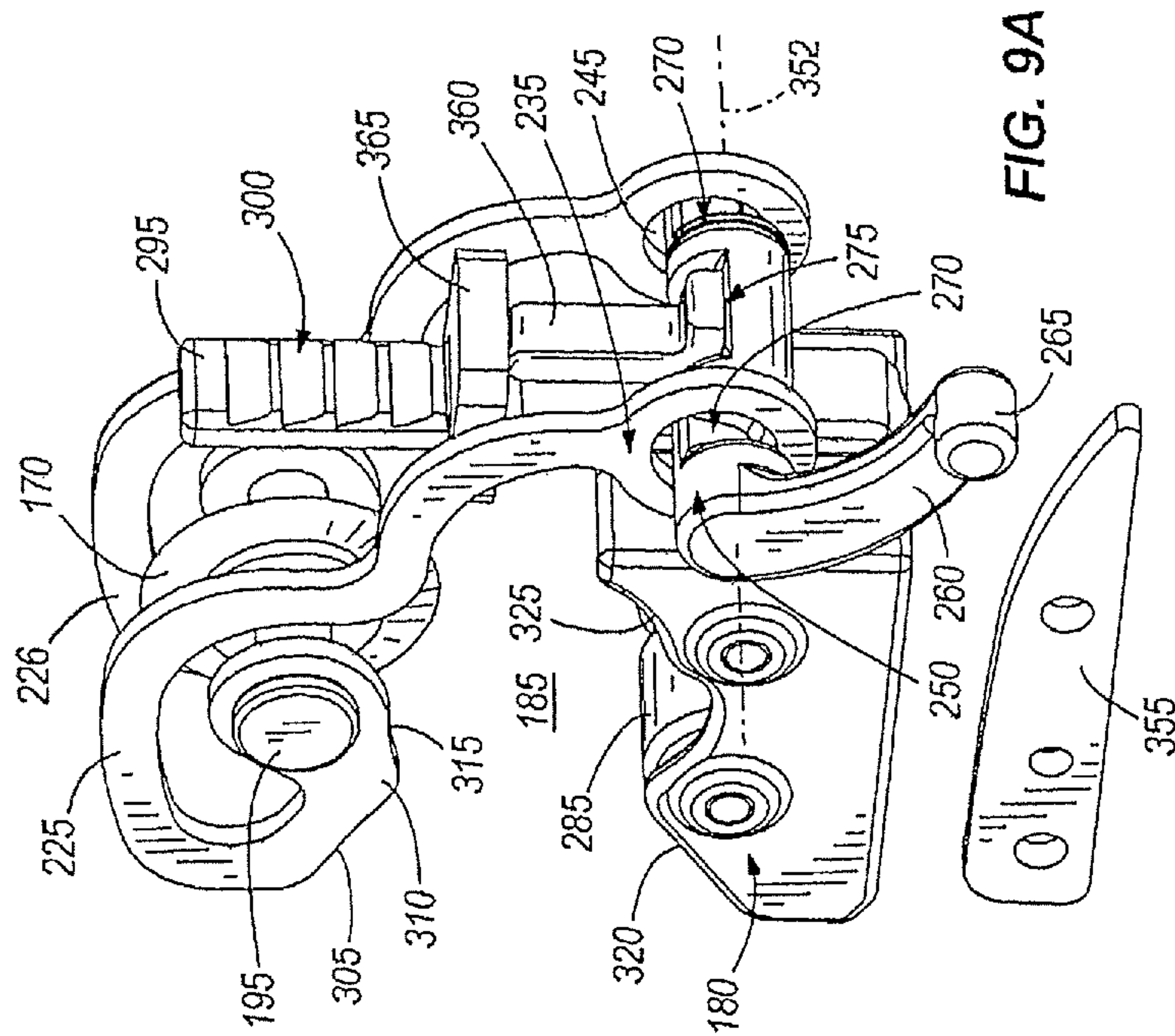
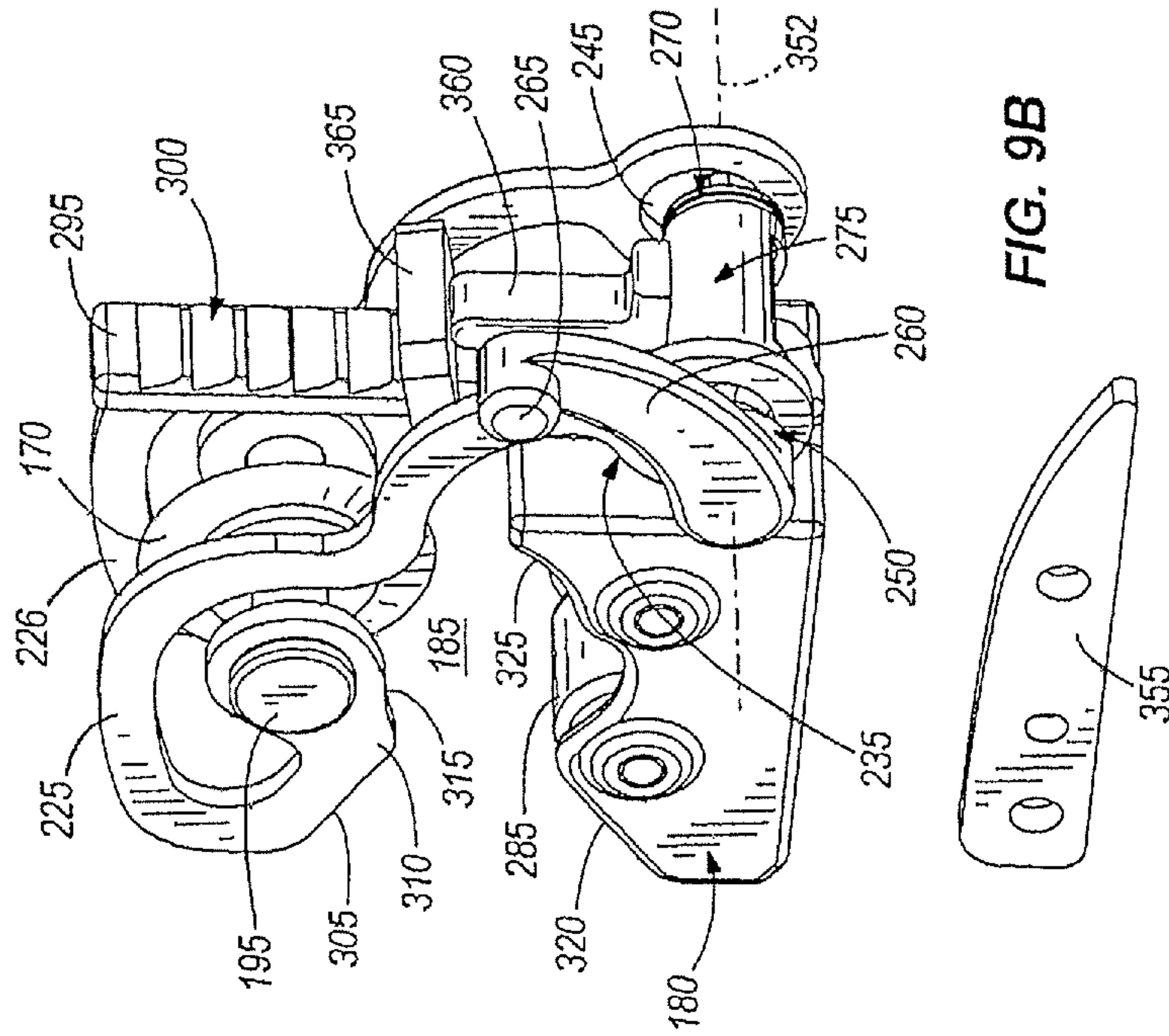


FIG. 8



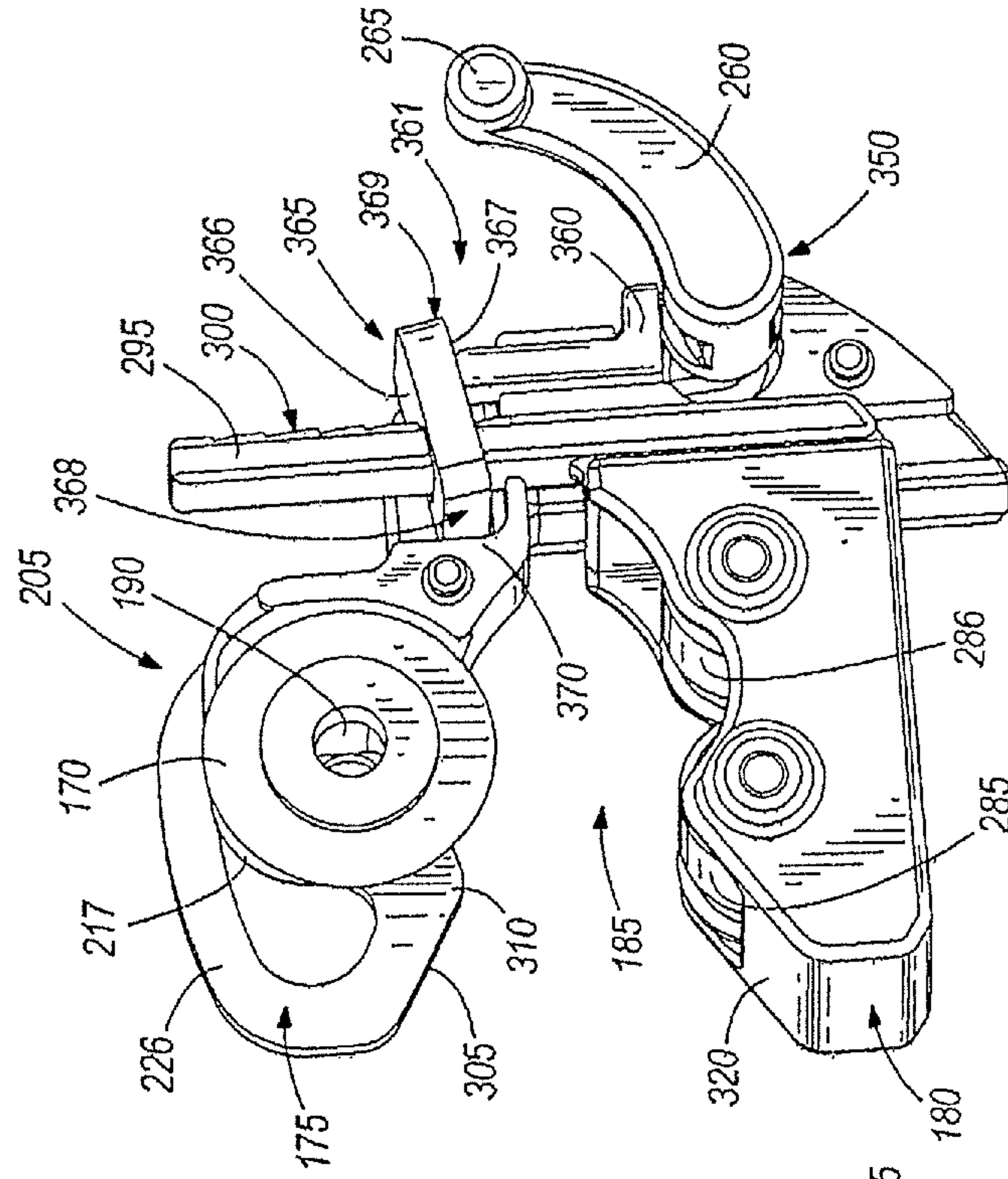


FIG. 11

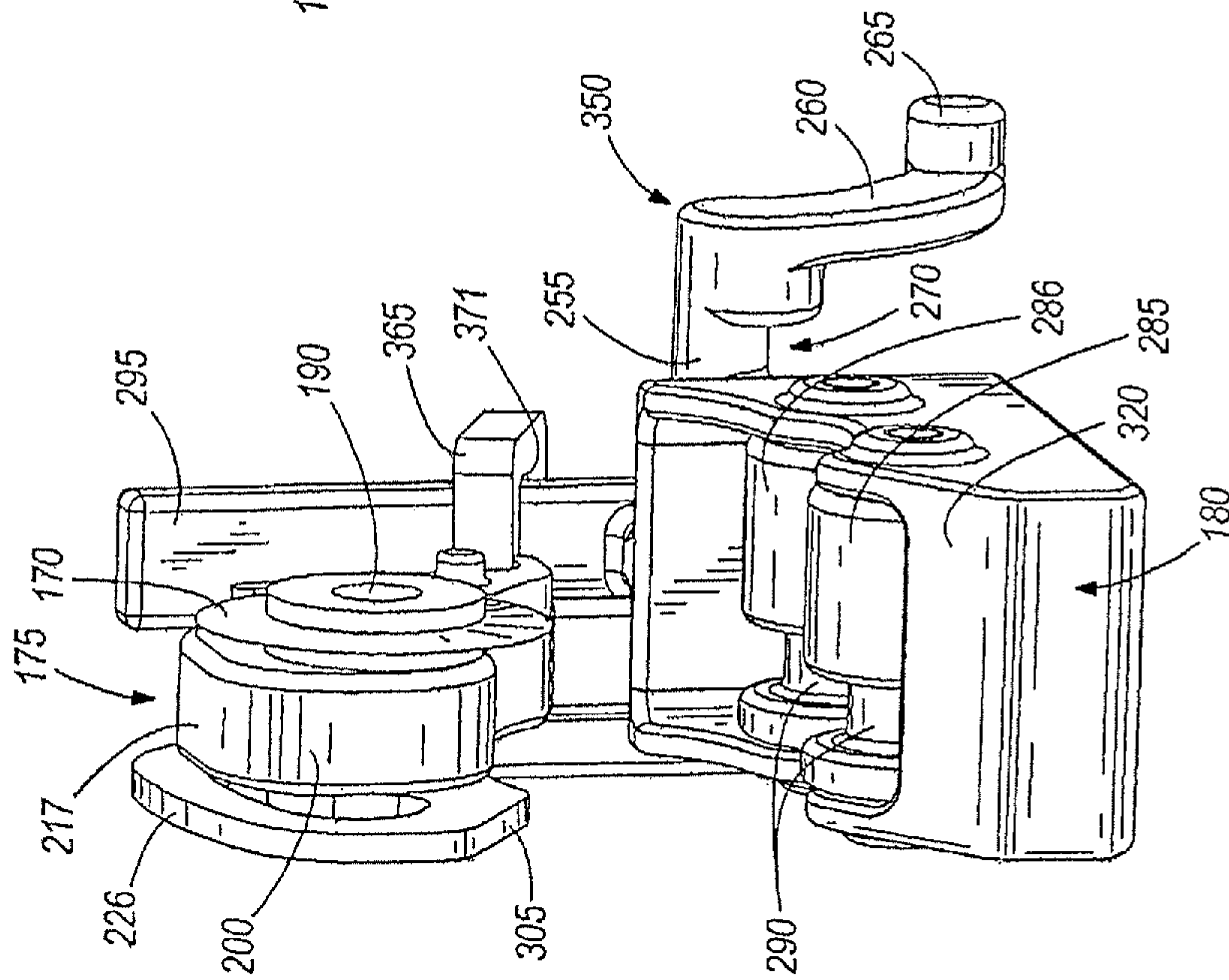
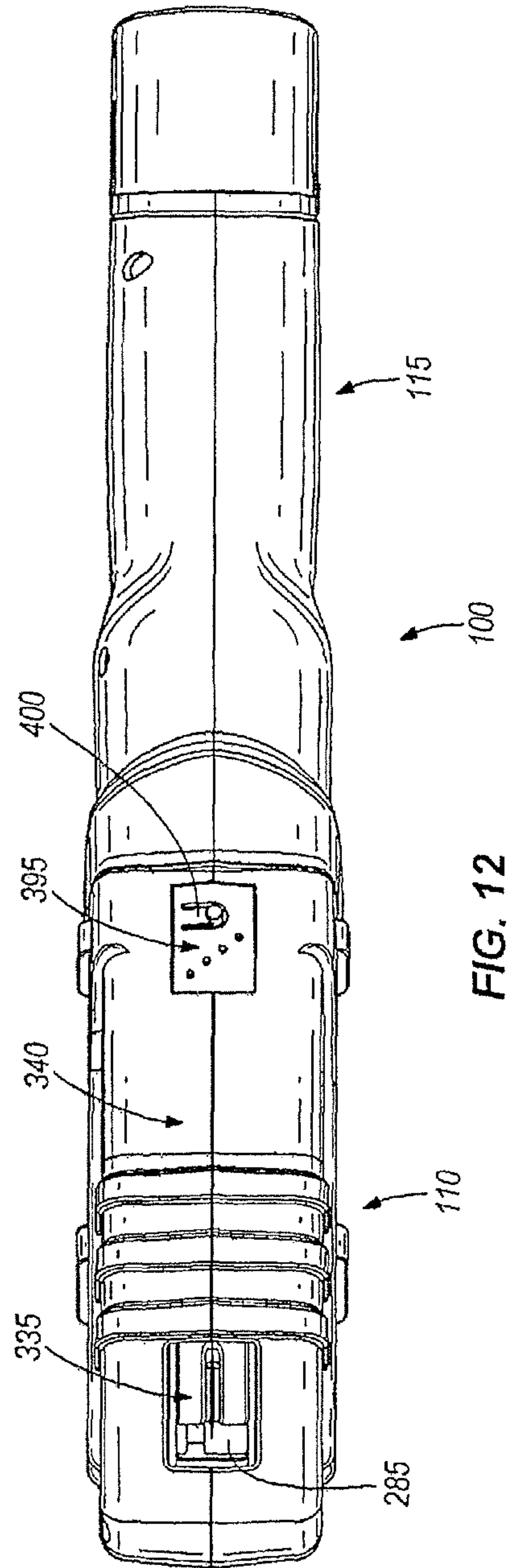


FIG. 10



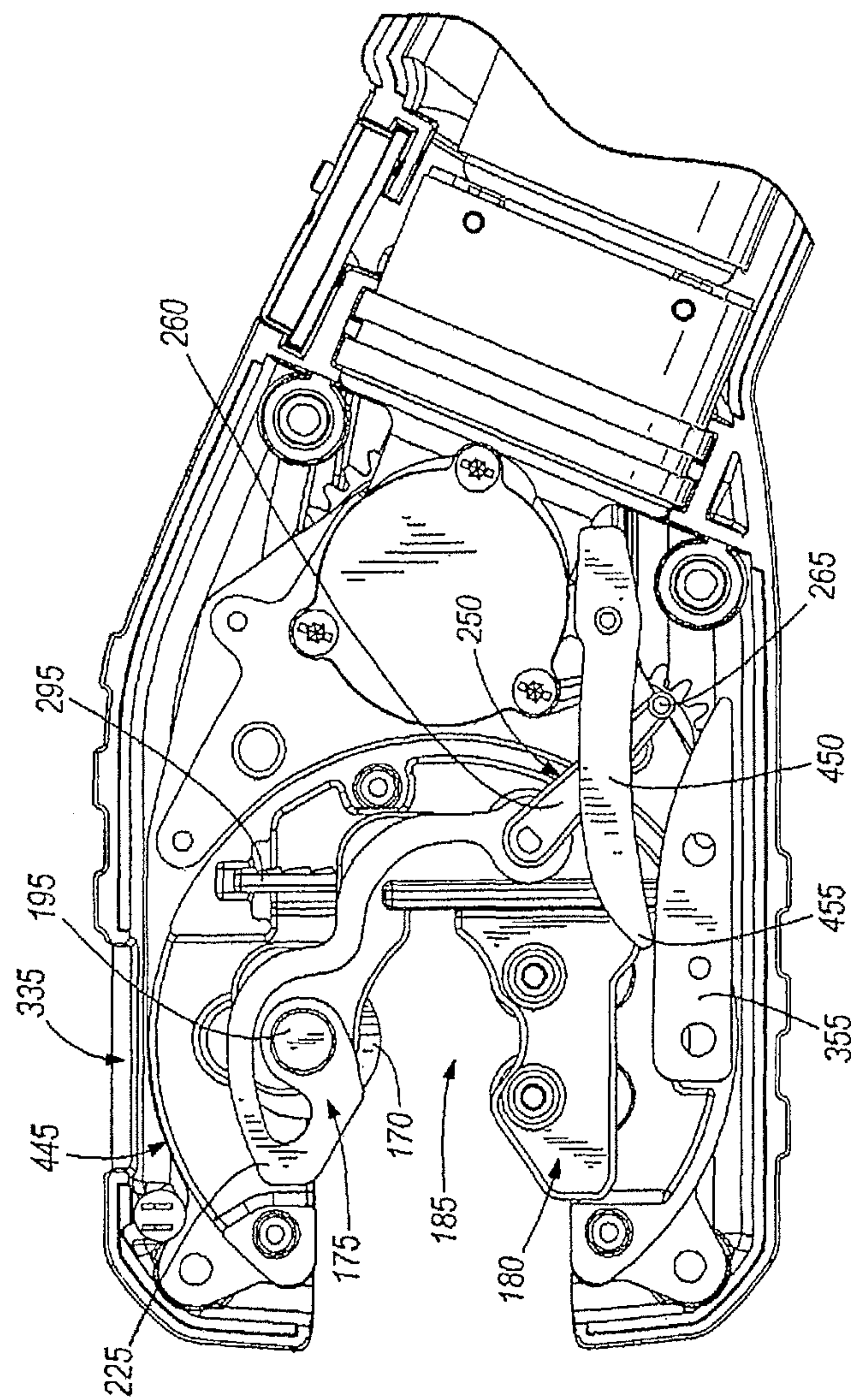


FIG. 13

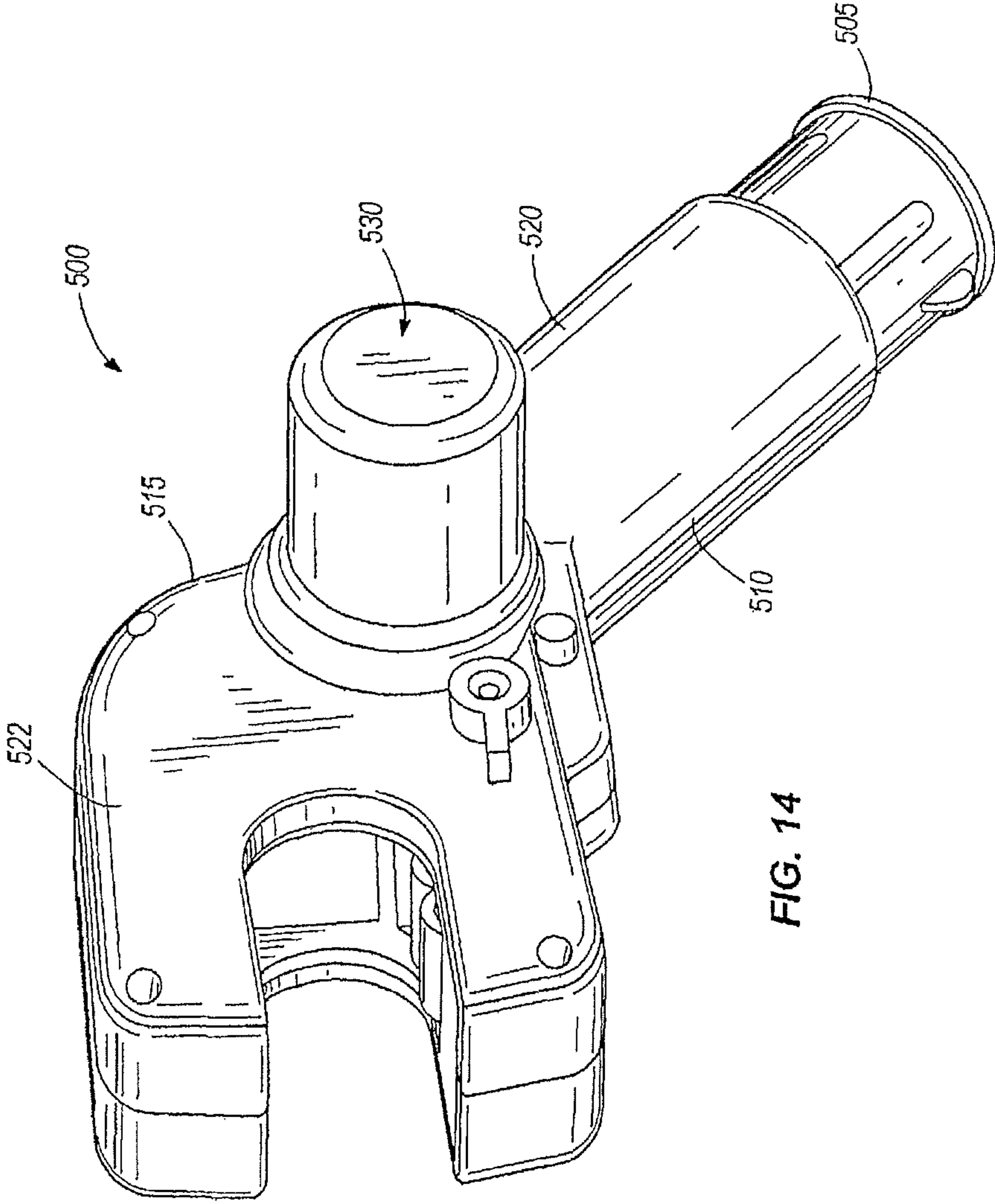
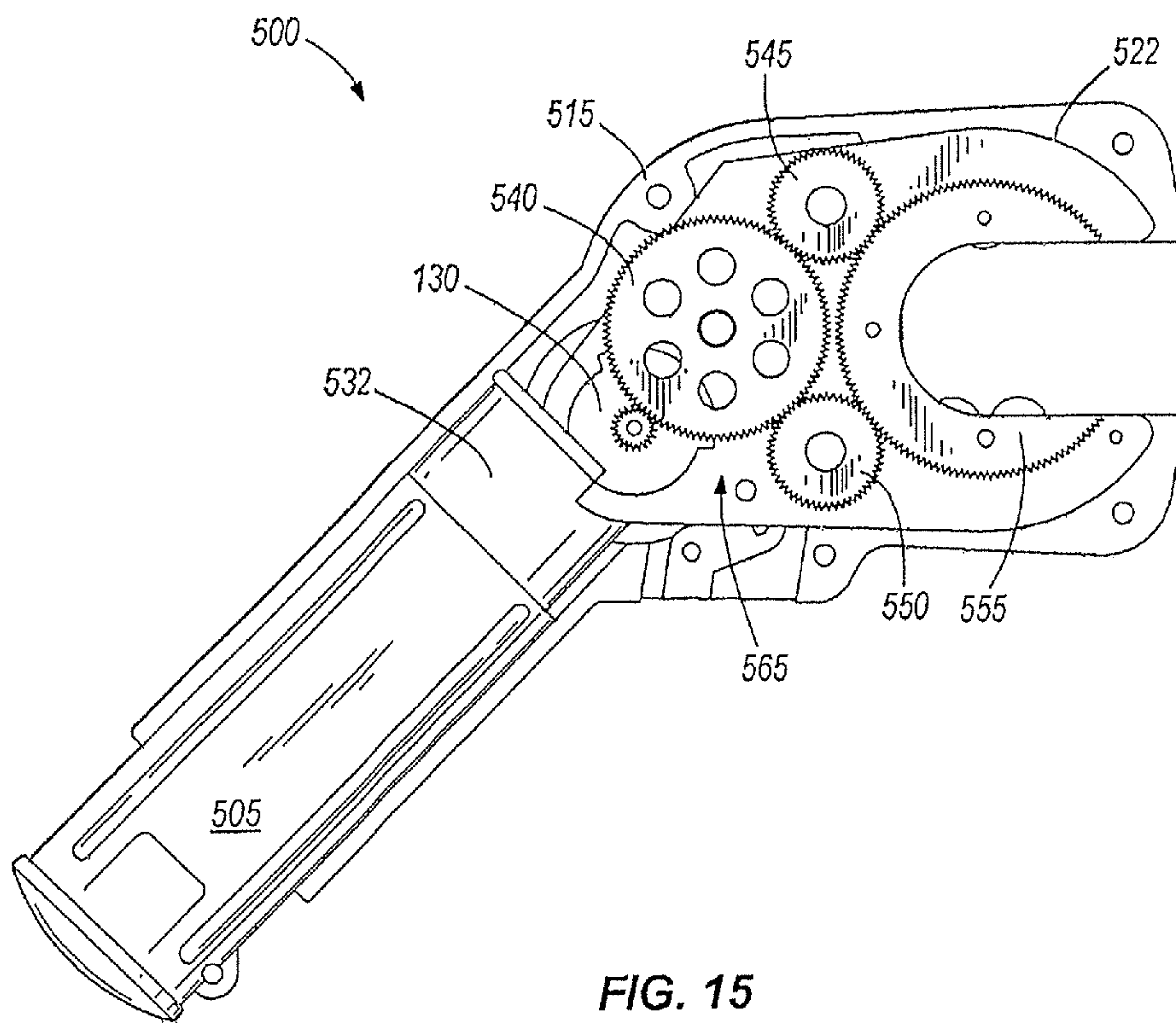


FIG. 14



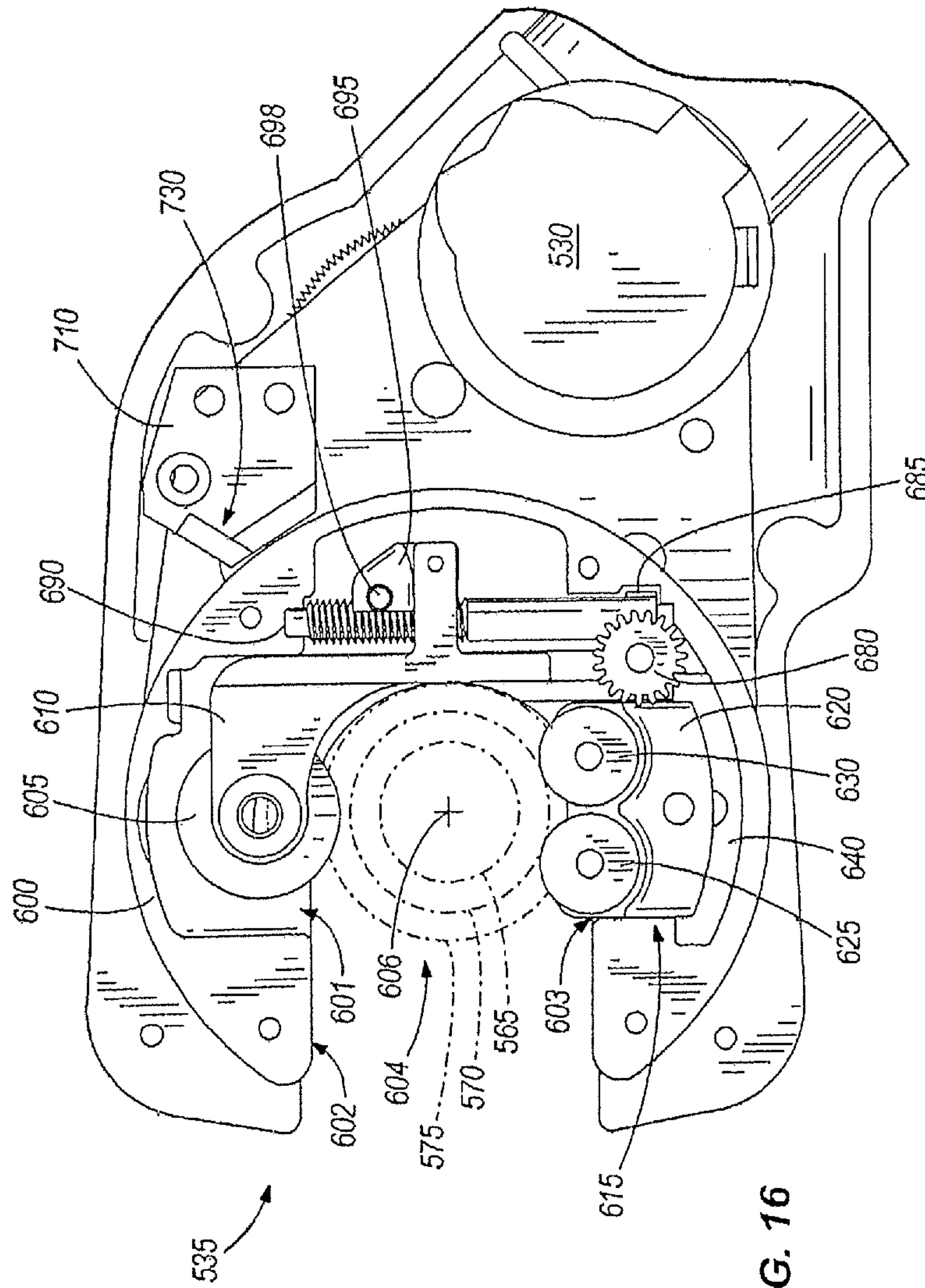


FIG. 16

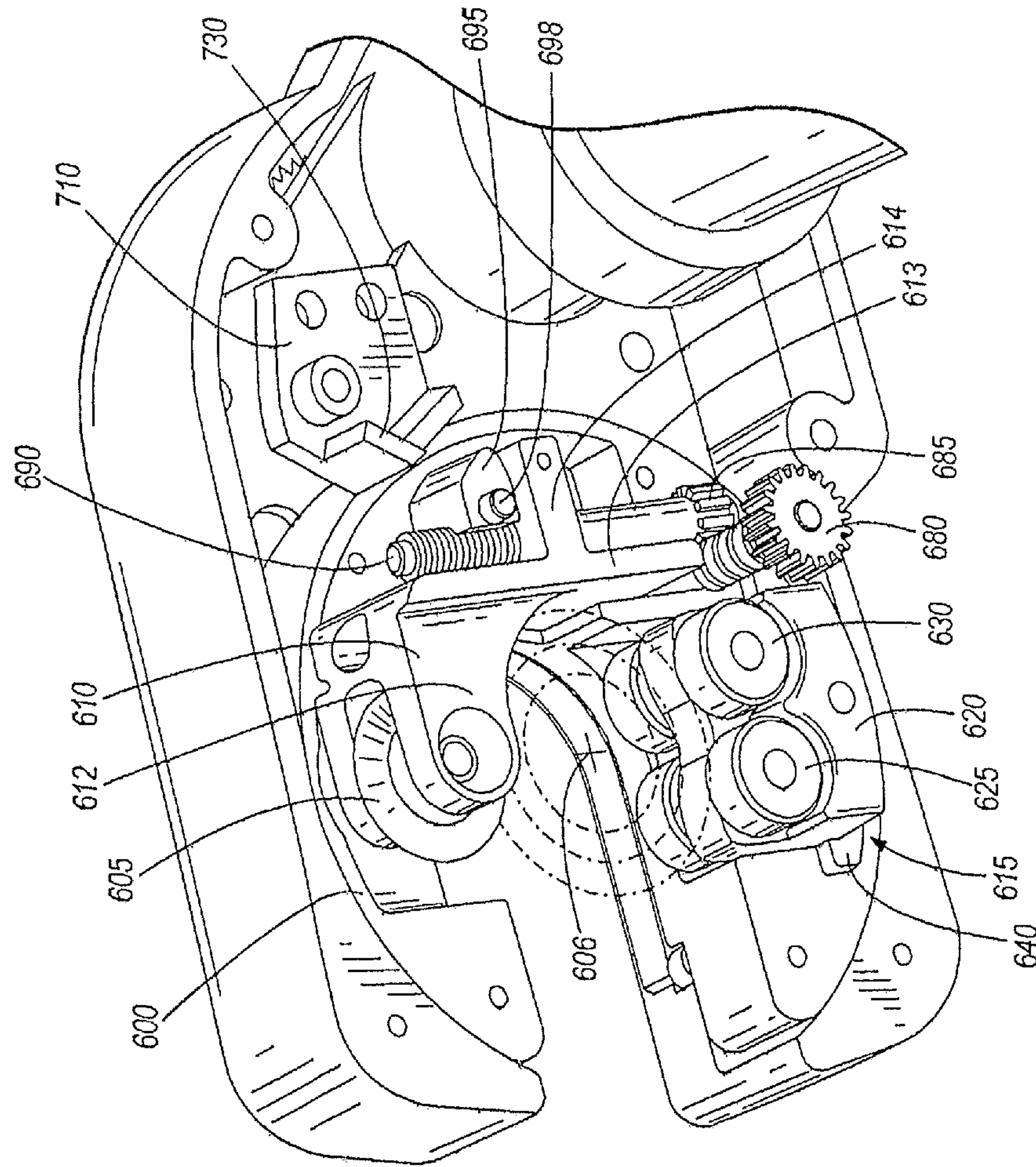


FIG. 17

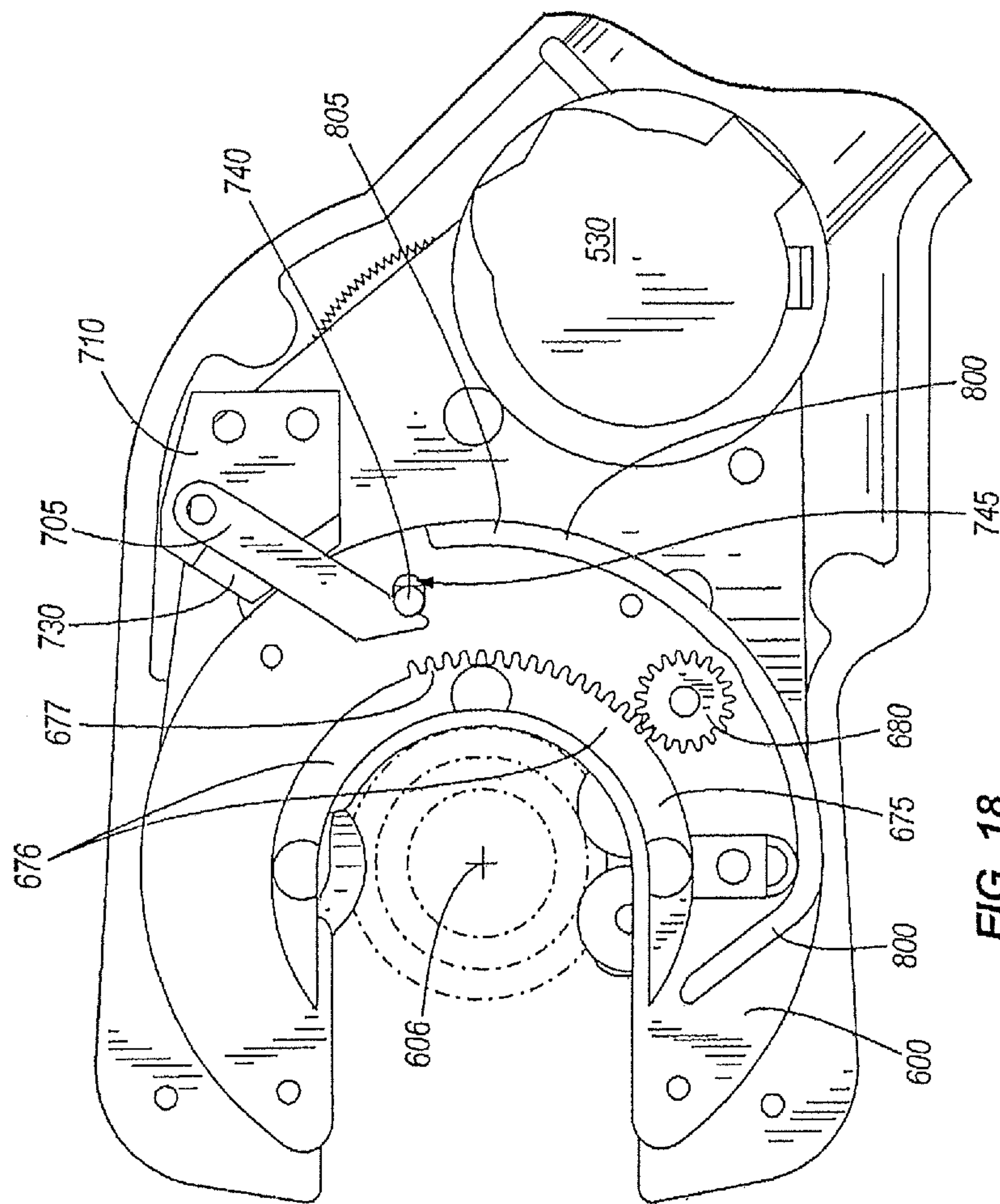
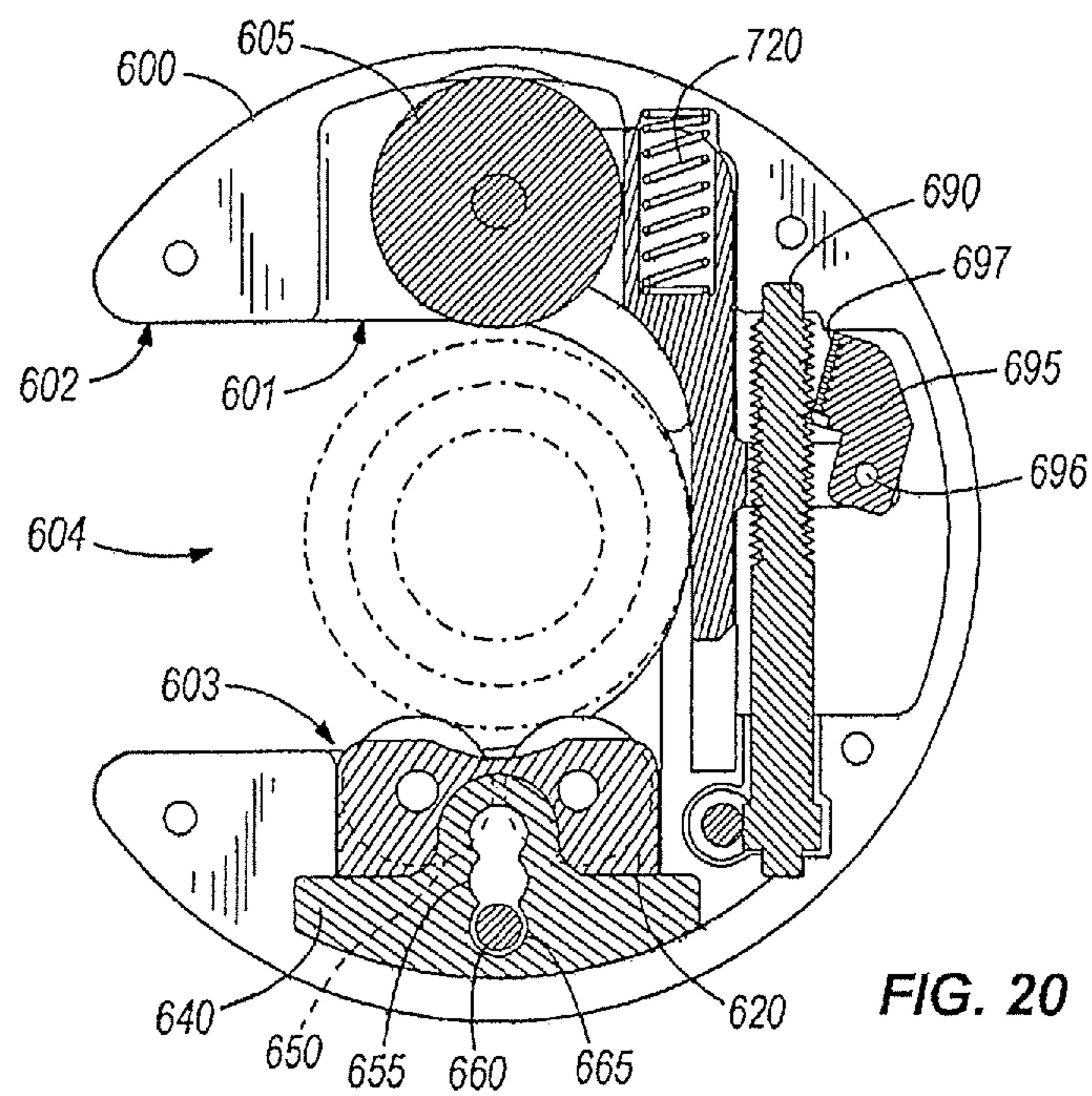
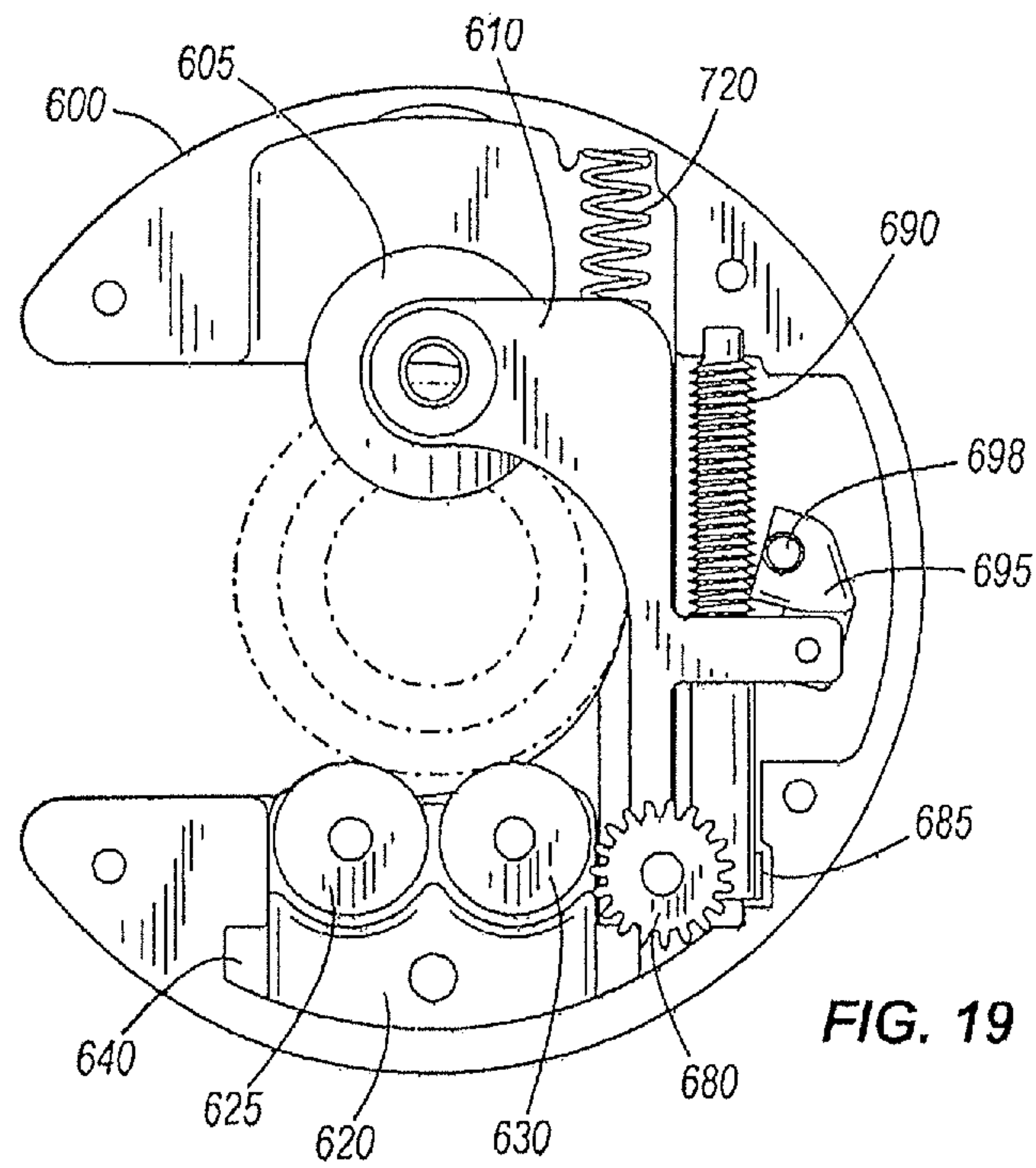


FIG. 18



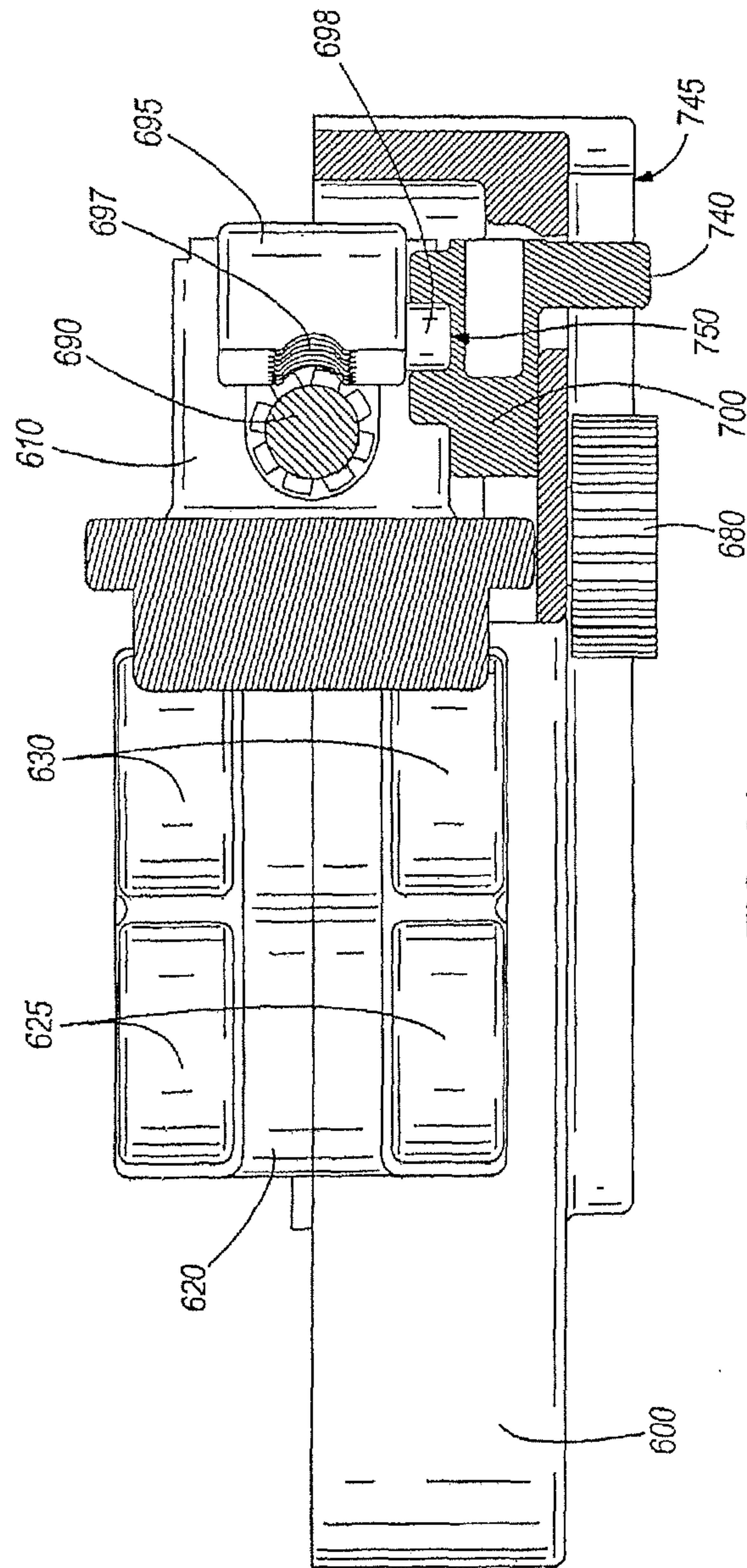


FIG. 21

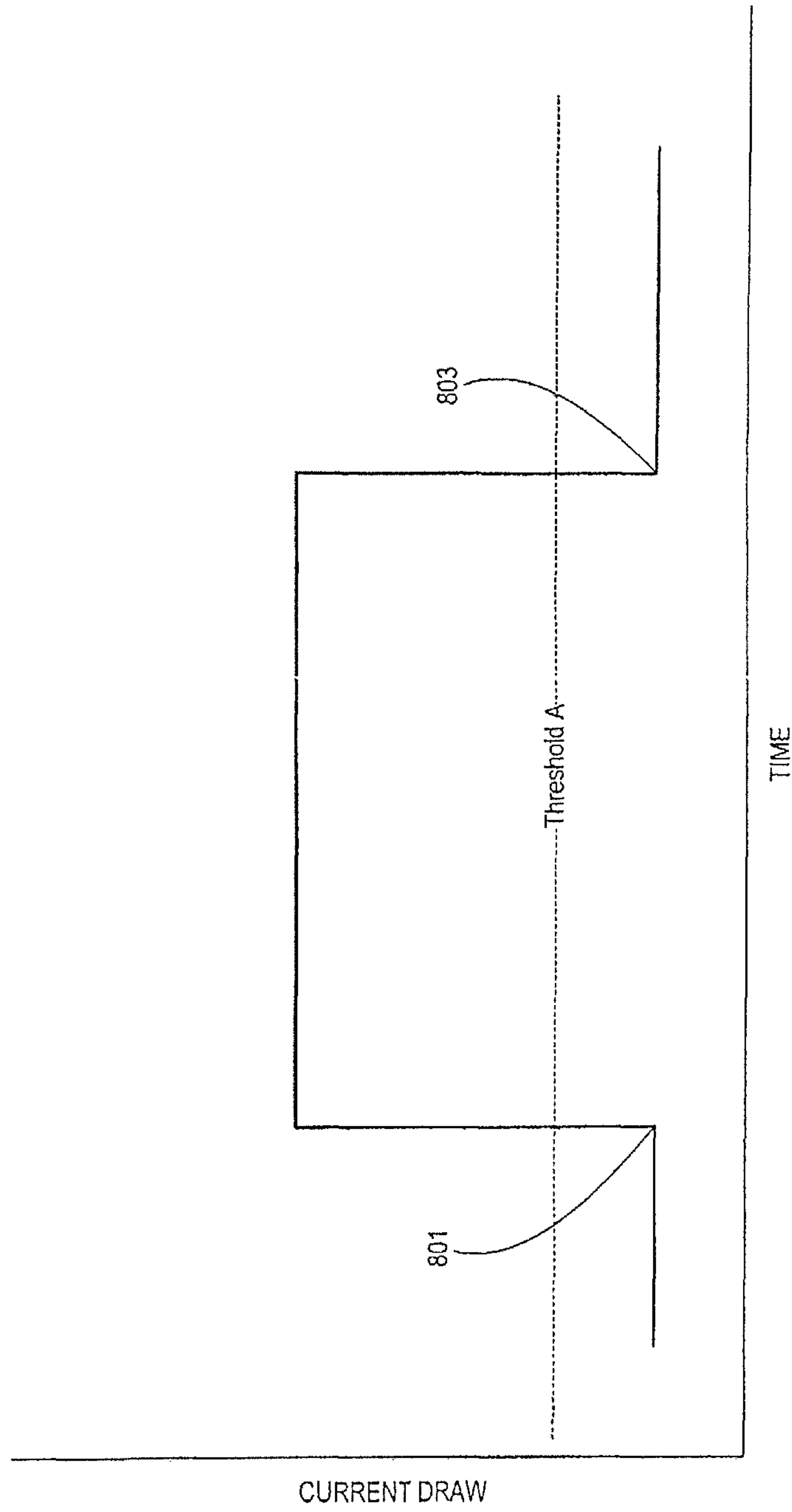


FIG. 22

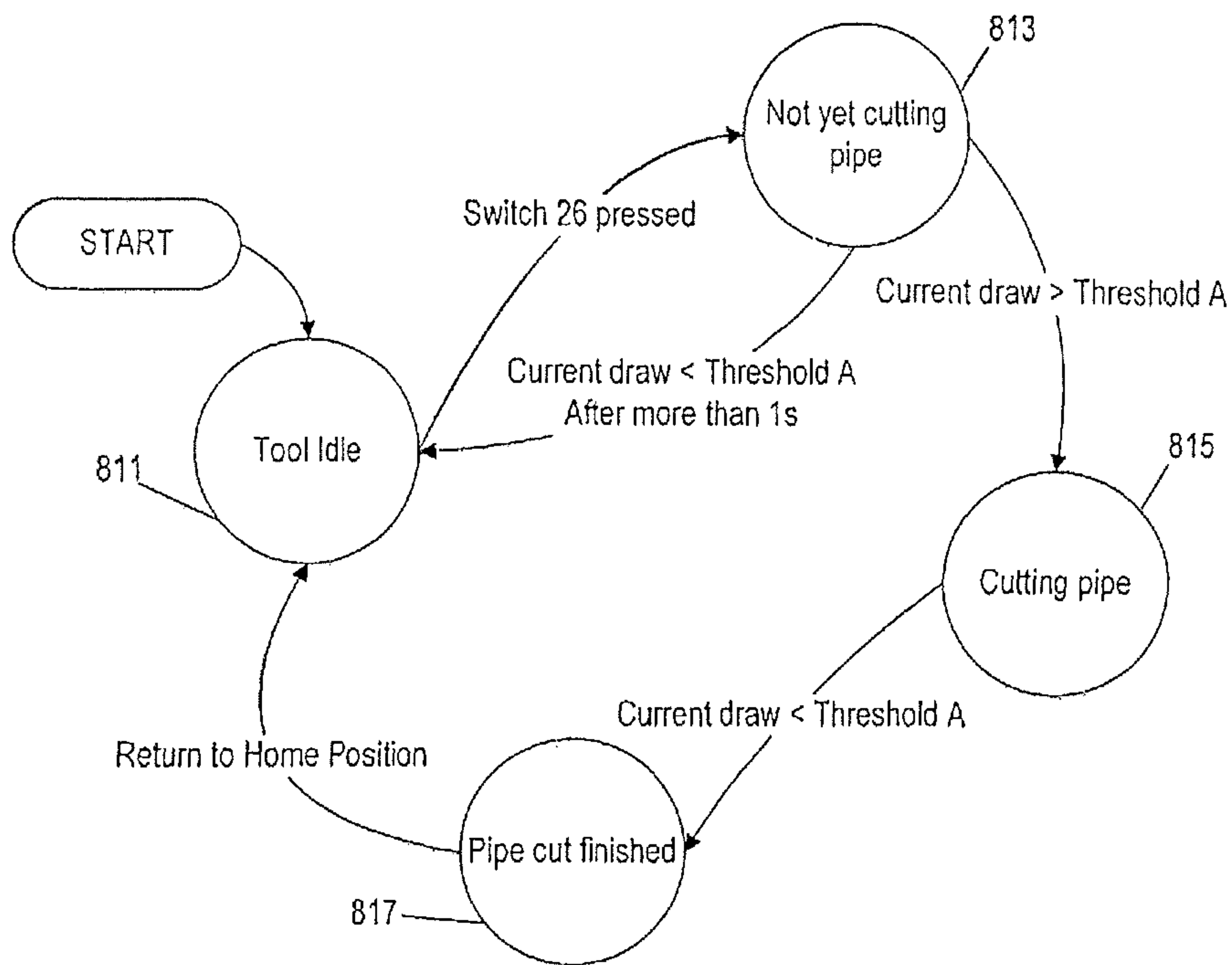


FIG. 23A

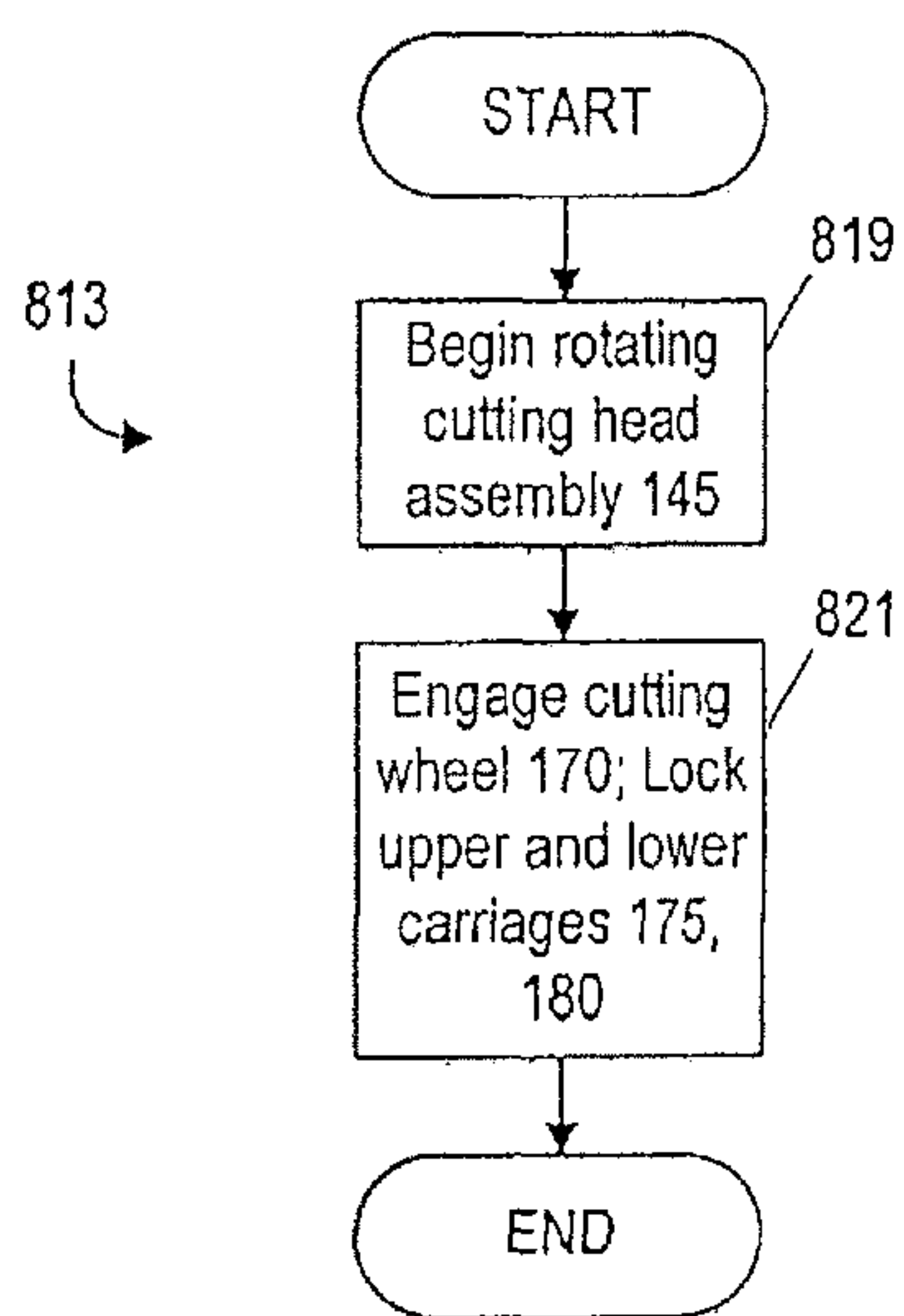


FIG. 23B

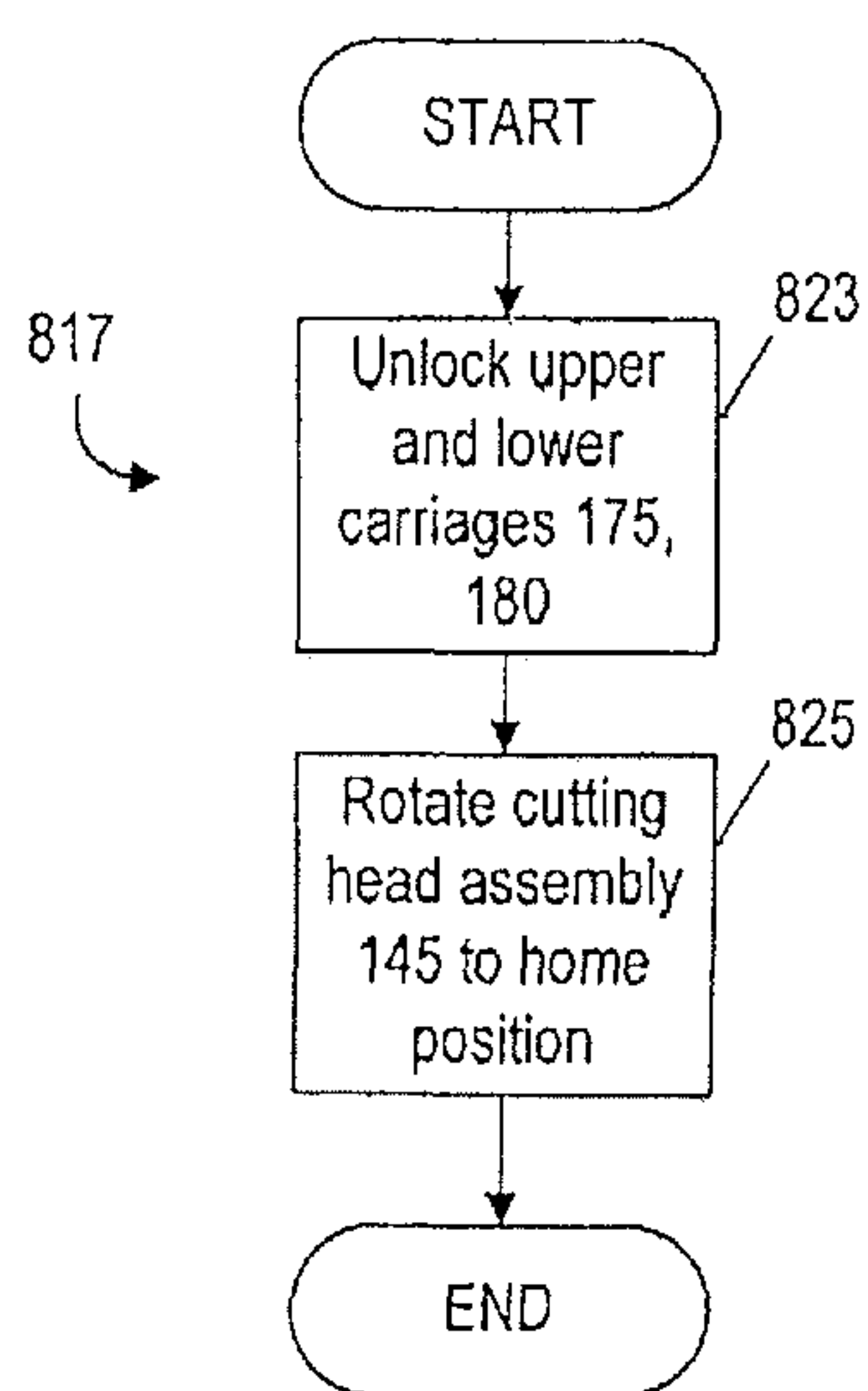


FIG. 23C

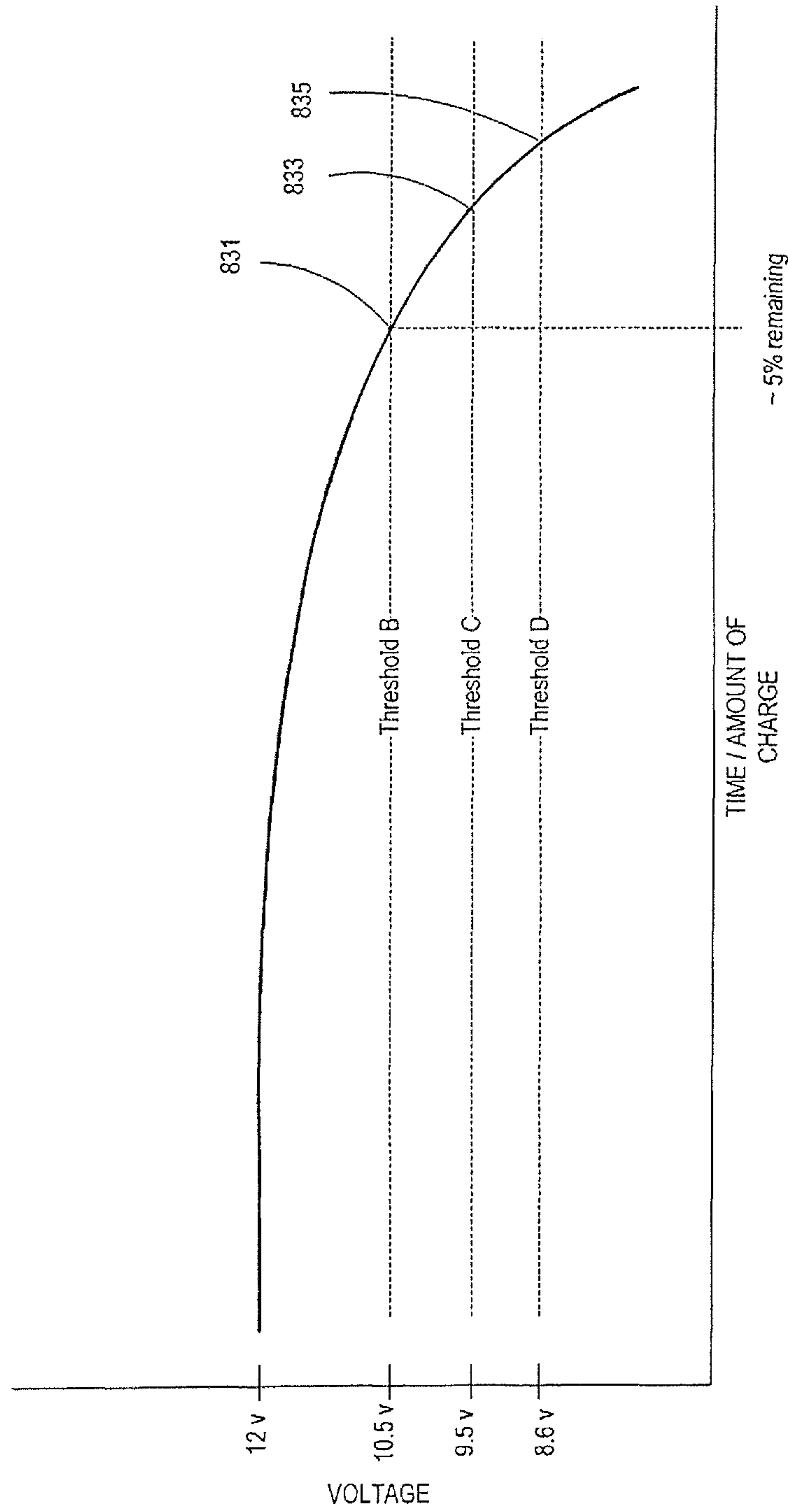


FIG. 24

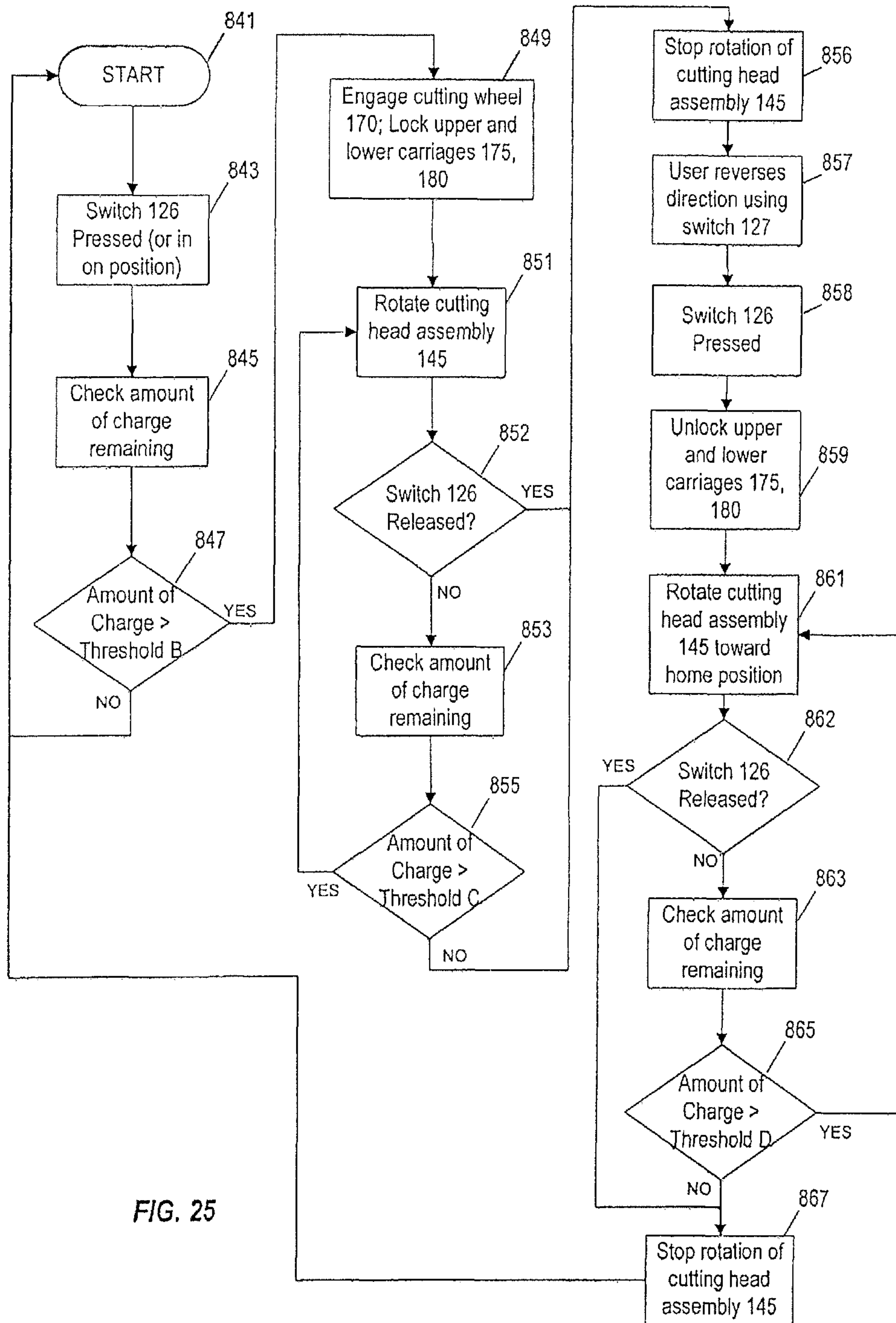


FIG. 25

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PIPE CUTTER

CROSS-REFERENCE TO RELATED
APPLICATIONS

The present patent application claims priority to International Application No. PCT/US08/57147, titled "PIPE CUTTER" filed on Mar. 14, 2008, which claims priority to U.S. Provisional Patent Application Ser. Nos. 60/895,062, filed on Mar. 15, 2007, and 60/990,862, filed on Nov. 28, 2007, the entire contents of which are all hereby incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention relates generally to a power tool and more specifically, to power management and automated operations of a pipe cutter. Power operated pipe cutters perform cutting operations in a variety of manners, many of which are largely automated. However, these methods of cutting oftentimes require manual intervention at some point during the cutting process, including, for example, loading a pipe within the pipe cutter, adjusting the pipe cutter to accommodate different pipe sizes, and applying a cutting force to the pipe. Such manual intervention can be time consuming and result in imperfect cuts. Power tools are also known that utilize rechargeable batteries; however, such batteries may be permanently damaged by overdischarge.

SUMMARY OF THE INVENTION

In one embodiment, the invention provides a power tool that includes a motor configured to perform an operation and a controller. The controller is configured to monitor the state of charge on a battery connected to the electric load. The state of charge is compared to a threshold. The threshold is greater than the state of charge needed by the motor to perform the operation. If the state of charge is less than or equal to the threshold, the controller prevents the electric load from operating. In some embodiments, the threshold is greater than the state of charge required to perform the operation from start to finish.

In another embodiment, the controller is further configured with a second threshold. The second threshold is greater than a state of charge indicative of an overdischarged condition that would cause damage to the lithium-based battery. In some embodiments, if the state of charge is less than or equal to the second threshold, the controller causes the electric load to cease all operations.

In yet another embodiment, the power tool is a pipe cutter for cutting a pipe. The pipe cutter also includes a cutting head assembly that cuts a pipe by rotating around the circumference of the pipe. An electric motor is configured to rotate the cutting head assembly. The controller is configured to detect when the pipe cutting assembly has finished cutting a pipe and then rotate the pipe cutting assembly to the home position.

In still another embodiment, the invention provides a pipe cutter for cutting a pipe. The pipe cutter is connectable to a rechargeable battery pack and includes a cutting head assembly, an electric motor, and a controller. The cutting head assembly is configured to cut a pipe by rotating around the circumference of the pipe. The electric motor is powered by the rechargeable battery pack and is configured to rotate the cutting head assembly. The controller stores three thresholds. The first threshold is greater than the state of charge needed to cut the pipe. The second threshold is lower than the first threshold, but greater than the state of charge required to

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return the cutting head assembly to a home position. The third threshold is lower than the second threshold, but greater than an over-discharge condition that would cause damage to the rechargeable battery pack. The controller is further configured to monitor the state of charge in the rechargeable battery pack. If the state of charge is less than the first threshold and the electric motor is stopped, the controller prevents the electric motor from being started. If the state of charge is less than the second threshold and the cutting head assembly is cutting a pipe, the controller stops the cutting operation and returns the cutting head assembly to the home position. If the state of charge is less than the third threshold and the electric motor is running, the controller stops the electric motor.

In another embodiment, the invention provides a power tool comprising a moveable assembly configured to perform an operation by moving from a home position, a motor configured to move the moveable assembly, a battery electrically coupled to the motor, and a controller. The controller is configured to operate the direction and rotation of the motor, detect when the moveable assembly is in the home position, and detect when the moveable assembly has completed performance of the operation. The controller is further configured to operate the motor such that the moveable assembly moves to the home position upon detecting that the moveable assembly has completed performance of the operation.

Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a pipe cutter according to one embodiment of the invention.

FIG. 2A is a side view of the pipe cutter shown in FIG. 1 with housing portions of the pipe cutter removed to illustrate internal gear mechanisms.

FIG. 2B is a perspective view of a handle portion of the pipe cutter shown in FIG. 1 with a battery pack disengaged from the pipe cutter.

FIG. 3 is a perspective view of the pipe cutter shown in FIG. 1 with housing portions of the pipe cutter removed to illustrate a cutting head assembly.

FIG. 4 is an enlarged view of the cutting head assembly shown in FIG. 3.

FIGS. 5A-5D illustrate various positions of the cutting head assembly shown in FIG. 4 during a cutting operation.

FIG. 6 is a bottom view of a portion of the cutting head assembly shown in FIG. 4.

FIGS. 7A-7C illustrate the cutting head assembly shown in FIG. 4 during insertion of the pipe.

FIG. 8 is a perspective view of the upper and lower carriages shown in FIGS. 6-7C with portions of the upper carriage, including a spring, removed to illustrate an upper carriage body.

FIGS. 9A-9B are perspective views of the upper and lower carriages shown in FIGS. 6-8 with portions of the upper carriage body removed.

FIG. 10 is a front perspective view of the upper and lower carriages shown in FIGS. 6-9 with portions of the upper carriage removed to illustrate a cutting wheel.

FIG. 11 is a side perspective view of the upper and lower carriages shown in FIG. 10.

FIG. 12 is a top view of the pipe cutter shown in FIG. 1.

FIG. 13 is side view of a cutting head portion of another embodiment of a pipe cutter with housing portions of the pipe cutter removed to illustrate a cutting head assembly.

FIG. 14 is a perspective view of a pipe cutter according to yet another embodiment of the invention.

FIG. 15 is a side view of the pipe cutter shown in FIG. 14 with housing portions of the pipe cutter removed to illustrate a drive assembly.

FIG. 16 is a side view of a forward portion of the pipe cutter shown in FIG. 14 with housing portions removed to illustrate a cutting head assembly.

FIG. 17 is a perspective view of the cutting head assembly shown in FIG. 16.

FIG. 18 is another side view of the cutting head assembly shown in FIG. 14 with housing portions removed to illustrate a timing gear and portions of the cutting head assembly.

FIG. 19 is a side view of cutting head assembly of the pipe cutter shown in FIG. 16-17.

FIG. 20 is cross-section side view of the cutting head assembly shown in FIG. 19.

FIG. 21 is a top view of a portion of the pipe cutter shown in FIG. 16 with housing portions removed to illustrate a portion of the cutting head assembly.

FIG. 22 is a graph of current draw of an electric motor in the pipe cutter shown in FIG. 1 as the pipe cutter cuts a pipe.

FIG. 23A is a state chart showing logic operations performed by the pipe cutter shown in FIG. 1 as it cuts a pipe.

FIG. 23B is a flowchart of operations performed by the pipe cutter shown in FIG. 1 in a state before it begins to cut a pipe as shown in FIG. 23A.

FIG. 23C is a flowchart of operations performed by the pipe cutter shown in FIG. 1 in a state after it finishes cutting a pipe as shown in FIG. 23A.

FIG. 24 is a graph of a state of charge on the battery (in voltage) as the pipe cutter shown in FIG. 1 discharges the battery.

FIG. 25 is a flowchart of operations performed by the pipe cutter shown in FIG. 1 as it cuts a pipe.

Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of the construction and the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or carried out in various ways. For example, power management and automation systems and methods are described below in the context of a battery-powered pipe cutter. However, these systems and methods can also be applied to other power tools such as, for example, drills, screwdrivers, impact wrenches, and crimping tools.

DETAILED DESCRIPTION

FIGS. 1-16 show a pipe cutter 100 according to one embodiment of the invention. The pipe cutter 100 is a hand-held, battery-operated pipe cutter, although according to another embodiment, the pipe cutter 100 may be a corded pipe cutter. The pipe cutter 100 is configured to cut a variety of pipe sizes and materials. In the illustrated embodiment, the pipe cutter 100 is configured to cut metal pipes having $\frac{3}{8}$ inch through 1 inch nominal inner diameter (i.e., $\frac{1}{2}$ inch to $1\frac{1}{8}$ inch outer diameter). Such metal pipes may include any type of copper having thicknesses K, L, and M, electric metallic tubing (conduit) of $\frac{3}{4}$ inch and 1 inch, aluminum, brass, and other metal pipes.

The pipe cutter 100 includes a housing 105 having a forward portion 110 and a handle portion 115. The housing 105 forms an exterior of the pipe cutter 100 and contains various mechanical and/or electrical components of the pipe cutter 100. The housing 105 may be a hard plastic material, a metal

material, and/or any other material or combination of materials suitable for containing the various components of the pipe cutter 100. The forward portion 110 includes components configured for conducting a cutting function of the pipe cutter 100 and includes an opening 106 for receiving a pipe. The handle portion 115 is configured to be gripped by a user with one or two hands. The handle portion 115 also houses, supports, or is coupled to a variety of mechanical or electrical components of the pipe cutter 100.

In the illustrated embodiment, the handle portion 115 includes a battery pack 120, a switch assembly 125, and a motor 130. The pipe cutter 100 is operable to receive power from the battery pack 120. According to another embodiment, the pipe cutter 100 may be powered by an alternating current (AC) power provided via a corded plug electrically coupled to a wall outlet or any number of suitable powering options.

As shown in FIGS. 1-3, the battery pack 120 is removably coupled to the handle portion 115 to provide power to the pipe cutter 100. In the illustrated embodiment, the battery pack 120 is supported within a battery chamber 135 extending through a rearward end of the handle portion 115 of the housing 105. The battery pack 120 includes receptacles (not shown) configured to connect to battery terminals 133 located within the battery chamber 135. When the battery pack 120 is disengaged from the battery chamber 135, as shown in FIG. 2B, the battery terminals 133 are exposed. The battery pack 120 generally conforms to the contour of the handle portion 115 such that, when the battery pack 120 is inserted into the battery chamber 135, the battery pack 120 helps define and increase the size of the handle portion 115. When inserted or coupled, the battery pack 120 provides power to the motor 130 through a control circuit 131 or may power the motor 130 directly. The control circuit 131 controls various aspects of the pipe cutter 100, the motor 130 and/or the battery pack 120 and also monitors operation of the pipe cutter 100, state of charge on the battery pack 120, and other components as discussed in detail below. In some embodiments, the control circuit 131 includes a microcontroller (or microprocessor) and at least one analog-to-digital converter. The analog-to-digital converter can be part of the microcontroller or included as a separate component in the control circuit 131.

The battery pack 120 includes two actuators 132 to releasably secure the battery pack 120 in the battery chamber 135. Each actuator 132 is connected to a tab 134 that engages a corresponding recess 129 in the battery chamber 135 (FIG. 2B). Due to the resiliency of the material of the housing 105, the tabs 134 are biased away from the battery casing to engage the recesses. Depressing the actuators 132 moves the tabs 134 out of engagement with the corresponding recesses such that the battery pack 120 may be disconnected from the pipe cutter 100. This arrangement allows a user to quickly remove the battery pack 120 from the device 100 for recharging or replacement.

In the illustrated embodiment, the battery pack 120 is a twelve-volt (12V) rechargeable power tool battery pack. The illustrated battery pack 120 may include three (3) battery cells having, for example, a lithium (Li), lithium-ion (Li-ion), or other lithium-based chemistry. For example, the battery cells may have a chemistry of lithium-cobalt (Li—Co), lithium-manganese (Li—Mn) spinel, or Li—Mn nickel. In such embodiments, each battery cell may have a nominal voltage of about, for example, 3.6V, 4.0V, or 4.2V. In other embodiments, the battery cells may have a nickel-cadmium, nickel-metal hydride, or lead acid battery chemistry. In further embodiments, the battery pack 120 may include fewer or more battery cells, and/or the battery cells may have a different nominal voltage. In yet another embodiment, the battery

pack 120 may be a dedicated battery housed (partially or entirely) within the pipe cutter 100. The battery pack 120 may also be configured for use with other cordless power tools, such as drills, screwdrivers, grinders, wrenches, and saws.

The pipe cutter 100 shown in the illustrated embodiment also includes a switch assembly 125, which is operable to electrically connect the motor 130 to the battery pack 120. The switch assembly 125 includes a push, power switch 126 and a pivoting, direction switch 127 positioned on the handle portion 115 of the housing 105. When actuated by a user, the power switch 126 activates the power supply 120 of the pipe cutter 100. The direction switch 127 is movable between three positions: a forward position and a reverse position for controlling the rotational direction of the motor 130 and a cutting head assembly 145, and a lock-out position for preventing inadvertent powering of the motor 130.

The handle portion 115 and the switch assembly 125 may be gripped by a user in a number of ways. Referring to FIG. 1, the handle portion 115 includes a dual position grip configured to accommodate two different one-handed grip styles, a lower grip position and an upper grip position. In a lower grip position, a user grasps a lower hand grip 136 such that the switch assembly 125 is located between the user's hand and the forward portion 110 of the pipe cutter 100. The user actuates the switch assembly 125 with an index finger of the same hand that is gripping the handle portion 115. In an upper grip position, the user grasps an upper hand grip 137 such that the user's hand is positioned between the switch assembly 125 and the forward portion 110 of the pipe cutter 100. The user actuates the switch assembly 125 with a ring finger or pinky finger of the same hand that is gripping the handle portion 115. The option of using the lower grip position and the upper grip position allows a user to adjust a grip to best suit individual hand size and strength and to accommodate for confined workspaces or pipe configurations. It should be readily apparent to those of skill in the art that a user may utilize a two-handed grip style with the handle portion 115 of the pipe cutter 100.

Referring to FIGS. 2A and 3, a drive assembly 140 is supported by the forward portion 110 of the housing 105. The drive assembly 140 is powered by the motor 130 and drives the cutting head assembly 145 to cut a pipe (not shown). In the illustrated embodiment, the motor 130 is drivingly coupled to gears (not shown) housed within a gear case 149. The gears are drivingly coupled to a bevel gear set, including a bevel gear 153 and a bevel pinion 154, which drives the drive assembly 140. In a further embodiment, the motor 130 is coupled to a gear reduction, such as a planetary gear reduction, with a pinion which couples to and drives a drive gear 150. In yet another embodiment, the motor 130 is coupled directly to the drive assembly 140.

The drive assembly 140 also includes a clutch, such as a clutch 151 (FIG. 3). The clutch cam 151 is driven by the bevel gear 153 and is slidably coupled to a drive axle 152 of the drive gear 150. The clutch 151 functions when the pipe cutter 100 is operated in a reverse direction and is configured to slip out of engagement with the bevel gear 153 when the amount of torque placed on the drive assembly 140 exceeds a certain threshold. This threshold is reached during reverse operation of the cutting head assembly 145 as the cutting head assembly 145 is returned to its original "home" position and meets resistance to further rotation, as discussed below with respect to FIG. 5A. Meeting this resistance, the clutch 151 slips out of engagement with the bevel gear 153 and slides along the drive axle 152. Disengagement of the clutch 151 and the bevel gear 153 terminates rotation of the drive axle 152 and thus, terminates rotation of the entire drive assembly 140 and the cutting

head assembly 145. In another embodiment, the drive assembly 140 includes a single two-direction clutch that operates in both forward and reverse directions.

As shown in FIG. 2A, the drive assembly 140 includes the drive gear 150, a first idler gear 155, a second idler gear 160, and a C-shaped head gear 165. The drive gear 150, the first idler gear 155, and the second idler gear 160 are mounted to a stationary frame 172, which is supported by the housing 105. The head gear 165 is coupled to the cutting head assembly 145 such that an opening 173 in the head gear 165 is aligned with an opening 171 in the cutting head assembly 145. In the illustrated embodiment, the first and second idler gears 155, 160 are spaced apart a distance such that at least one of the first and second idler gears 155, 160 is in contact with the head gear 165 at all times, even when the opening 173 of the head gear 165 rotates past the idler gears 155, 160.

The handle portion 115 of the housing 105 and the forward portion 110 of the housing 105 are separated by a seal 174 (FIG. 2A) that serves to waterproof the pipe cutter 100 for use in wet conditions. The seal 174 may take a variety of forms, such as an O-ring or other type of seal. In the illustrated embodiment, the seal 174 is an O-ring that prevents liquid from entering the pipe cutter 100 at any point rear of the drive assembly 140. The O-ring 174 is located in a circumferential groove formed in the gear casing 149. So that the pipe cutter 100 may be safely used in potentially wet conditions, the pipe cutter 100 components forward of the seal 174 may be formed of materials appropriate for use in water and resistant to excessive wear and tear under such conditions. In the illustrated embodiment, all components contained within the forward portion 110 of the housing 105 are fowled of stainless steel or, in the case of a cutting wheel 170, aluminum.

As shown in FIGS. 3-4, the cutting head assembly 145 is located in the forward portion 110 of the housing 105. FIGS. 5A-5D illustrate the cutting head assembly 145 with the housing 105 and the remainder of the pipe cutter 100 removed, and the cutting head assembly 145 in a variety of positions during a cutting operation. In the illustrated embodiment, the cutting head assembly 145 includes a cutting head housing 146, which contains an upper carriage 175 and a lower carriage 180. A space between the upper carriage 175 and the lower carriage 180 forms a cutting area 185 into which pipes of various sizes are inserted. In the illustrated embodiment, the upper carriage 175 and lower carriage 180 are configured to move independently of each other so that a pipe is inserted without having to preconfigure the size of the cutting area 185 for the pipe's diameter. The upper and lower carriages 175, 180 may be formed from a variety of materials including metal and plastic. Although the upper and lower carriages 175, 180 are configured to move independently, the carriages 175, 180 are coupled by one or more parts, couplers, fasteners, pivot points, etc. As shown in FIG. 6, the upper and lower carriages 175, 180 are slidably coupled together at a stem 295 of the lower carriage 180. Although the carriages 175, 180 are described as upper and lower carriages, it should be understood that they may be located relative to each other in a different manner. For example, the carriage described as the upper carriage 175 may be located in the position of the lower carriage 180 and vice versa.

In the illustrated embodiment, the upper carriage 175 includes the cutting wheel 170, such as a blade. The cutting wheel 170 is a sharp blade suitable for cutting pipe of various materials, including metal. The cutting wheel 170 may be formed of various types of metal depending on the type of pipe to be cut, and may include abrasive particles. The illustrated cutting wheel 170 is circular, although the cutting tool may be formed in varying other shapes, such as an oval shape,

a polygon, etc. The cutting wheel **170** may have a smooth and sharp edge, may have an uneven or asymmetrical edge with teeth or protrusions, or otherwise. In the illustrated embodiment, the cutting wheel **170** is formed of aluminum and has a circular shape with a smooth edge. The cutting wheel **170** includes a central aperture **190** (FIGS. 10-11). The central aperture **190** may be circular or have another shape. The cutting wheel **170** may be permanently fixed within the pipe cutter **100** or may be replaceable. The upper carriage **175** further includes an axle **195** that is coupled to the cutting wheel **170** at the aperture **190** and around which the cutting wheel **170** rotates.

Referring to FIGS. 7A-7C and 8-11, the upper carriage **175** includes a body **200** configured to support the cutting wheel **170**. The body **200** of the upper carriage **175** includes an upper body portion **205** and a lower body portion **210**. The upper portion **205** of the upper carriage body **200** includes a space **215** separating a first upper body portion **216** and a second upper body portion **217** (FIG. 8). In the illustrated embodiment, the cutting wheel **170** is positioned within the space **215**. The first and second upper body portions **216**, **217** of the upper carriage body **200** each include an opening, such as a slot **220** (FIG. 8), in which the cutting wheel axle **195** rides. The slots **220** may be formed in a variety of shapes of sufficient size to support the axle **195**. In the illustrated embodiment, the slots **220** are formed such that the cutting wheel axle **195** has sufficient room to move up and down within the slots **220**, and thereby move toward and away from the lower carriage **180**.

The upper carriage **175** includes one or more biasing mechanisms, such as springs **225**, **226** shown in the illustrated embodiment. Each of the springs **225**, **226** includes a first portion **230** and a second portion **235**, whereby the first portions **230** include one or more apertures (not shown) aligned with the slots **220** of the upper carriage body **200** and through which the cutting wheel axle **195** is mounted. The cutting wheel **170** rides on the axle **195**, which rests within the slots **220** of the upper carriage body **200** and the apertures of the first portions **230** of the first and second springs **225**, **226**.

Each of the first and second springs **225**, **226** includes an aperture **245** in the second portion **235**. The apertures **245** are configured to receive and interact with a mechanical element of the upper or lower carriages **175**, **180**, such as a cam **250**. In the illustrated embodiment, the upper carriage **175** includes a rotatable cam **250** having a cam shaft **255**, a cam lever **260**, and a cam post **265**. As shown in FIGS. 9A and 9B, each of the second portions **235** of the springs **225**, **226** includes the aperture **245** for receiving the cam shaft **255**. The cam shaft **255** extends through the first spring **225**, the second portion **210** of the upper carriage body **200** (FIG. 8), and the second spring **226**. In the illustrated embodiment, the cam shaft **255** is a dual cam shaft that serves two functions, an automatic spring-loading function and an automatic locking function, as discussed below. The cam lever **260** extends from one end of the cam shaft **255** and terminates at the cam post **265**. The cam shaft **255** has a generally cylindrical shape, and referring to FIG. 9A, includes first cam surfaces **270** and a second cam surface **275**. The first cam surfaces **270** act on the springs **225**, **226** to perform an automatic spring-loading function, and the second cam surface **275** acts on a lifter element **360** to perform an automatic locking function, as discussed below.

The lower carriage **180** is generally configured to provide a force against the pipe during pipe loading and pipe cutting activities. Referring to FIGS. 7A-7C, the lower carriage **180** is biased toward the upper carriage **175** and into the cutting area **185** by a spring **280**, such as a light spring. It should be

readily apparent to those of skill in the art that in a further embodiment the lower carriage **180** may be acted upon by any type of biasing element.

As shown in FIGS. 7A-7C, the lower carriage **180** includes a body **282** supporting rollers **285**, **286**, which define a support surface for a pipe. It should be noted that although two rollers are shown in the illustrated embodiment, one or more rollers or no rollers may be provided within the lower carriage **180** for defining a support surface. For example, the lower carriage **180** may include one or more surfaces, bumpers, or other structures configured to support and/or press against a pipe when a pipe is inserted into the cutting area **185**.

The first and second rollers **285**, **286** may be formed of a variety of materials, such as metal or plastic. In the illustrated embodiment, the first and second rollers **285**, **286** are formed of stainless steel. The rollers may also be formed in a variety of shapes, although in the illustrated embodiment, the rollers **285**, **286** are formed in generally cylindrical shapes. In the illustrated embodiment, circumferential grooves **290** (FIG. 10) are formed in the rollers to support a pipe with a flare fitting and allow a user to remove a flared end of a pipe while minimizing the length of pipe to be removed. The grooves **290** are located in an off-center position of each roller **285**, **286** relative to the cutting wheel **170**. The off-center location of the grooves **290** allows the flared end of a pipe to rest within the grooves **290** while the length of pipe is firmly supported by the first and second rollers **285**, **286** during the cutting operation.

Referring to FIGS. 6, 8 and 9A, the upper carriage **175** receives a stem **295**, or a support member, of the lower carriage **180** to slidably couple the upper and lower carriages **175**, **180** together. The stem **295** extends from the lower carriage body **282**, toward the upper carriage **175**, and adjacent to a rear of the cutting area **185**. The stem **295** may be integrally formed with the body **282** of the lower carriage **180** or may be a separate component coupled to the lower carriage body **282**. The stem **295** includes one or more notches **300** spaced such that each notch corresponds to a pipe diameter, as discussed below.

As shown in FIGS. 7A-7C, the upper and lower carriages **175**, **180** allow pipes having a variety of sizes to be quickly loaded into the pipe cutter **100** such that a pipe **302** is automatically aligned and supported within the cutting head assembly **145** prior to initiation of a cutting operation. To this end, the upper and lower carriages **175**, **180** are biased toward each other and shaped so as to guide a pipe into the cutting area **185**. The lower carriage **180** includes a forward portion having a forward angled surface **320** that extends toward the cutting area **185** and terminates along a centerline of the first roller **285**. Each of the first and second springs **225**, **226** include a forward angled surface **305** that extend to form a protrusion **310** on the lower surfaces of the springs **225**, **226**. The protrusions **310** are located opposite the first roller **285**. Moving inward from the protrusions **310**, each lower surface of the springs **225**, **226** defines a second angled surface **315** extending away from the lower carriage **180** and to the rear of the cutting area **185**.

As shown in FIG. 7A, the forward angled surface **305** of the first and second springs **225**, **226** and the forward angled surface **320** of the lower carriage **180** cooperate to guide a pipe **302** into the cutting area **185**. As such, the forward angled surfaces **305**, **320** may be symmetrical. The protrusions **310** of the cutting springs **225**, **226** cooperate with the first roller **285** (FIG. 7B) such that when the pipe **302** is forced past the protrusions **310** and the first roller **285**, the pipe **302** reaches an over-center position (FIG. 7C). In the over-center position, the pipe **302** is centered between the first and second

rollers **285, 286** of the lower carriage **180** and is aligned with the cutting wheel **170** of the upper carriage **175**.

The upper and lower carriages **175, 180** include surfaces **325, 330** to prevent the pipe **302** from moving too far into the cutting area **185** such that it would no longer be supported between the first and second rollers **285, 286** and the cutting wheel **170**, i.e., in the over-center position. As shown in FIGS. 7A-7C, a rear upper portion of the lower carriage **180** includes an angled surface **325** extending toward the upper carriage **175** and to the rear of the cutting area **185**. Likewise, a portion of the upper carriage **175** located to the rear of the cutting area **185** includes an angled surface **330** extending toward the lower carriage **180** and to the rear of the cutting area **185**.

In preparation for use of the pipe cutter **100**, a user selects a pipe **302** to be cut and positions the pipe **302** within the cutting area **185**. Prior to pipe insertion, the upper and lower carriages **175, 180** are independently and freely movable in an unlocked state. As the pipe **302** enters the cutting area **185**, the pipe **302** presses against the forward angled surfaces **305, 320** of the upper and lower carriages **175, 180**, as shown in FIG. 7A. The force of the pipe insertion overcomes the biases of the spring **280** on the lower carriage **180** and the springs **225, 226** on the upper carriage **175**, thereby forcing the upper and lower carriages **175, 180** away from each other, as shown in FIG. 7B. The force of the pipe's insertion on the first and second springs **225, 226** also moves the cutting wheel axle **195** and cutting wheel **170**, away from the lower carriage **180**. The movement of the upper and lower carriages **175, 180** away from each other accommodates the specific diameter of the pipe **302** and allows the pipe **302** to move further into the cutting area **185**. As the pipe **302** continues to move into the cutting area **185**, the pipe **302** passes the protrusions **310** on the upper carriage **175** and the first roller **285** of the lower carriage **180** in a centered position. As the pipe **302** moves past the protrusions **310** and the first roller **285**, the pipe **302** reaches an over-center position, as shown in FIG. 7C. When the pipe **302** reaches this over-center position, the upper and lower carriages **175, 180** snap onto the pipe **302** such that the pipe **302** is firmly supported between the rollers **285, 286** and the cutting wheel **170**.

When inserting the pipe into the pipe cutter **100** as described above, the user may view the cutting area **185** through a sight window **335** (FIG. 12). In the illustrated embodiment, the pipe cutter **100** includes a sight window **335** located in a wall **340** of the housing **105** proximate the cutting head assembly **145**. The sight window **335** allows a user to view the cutting area **185** of the pipe cutter **100** through the wall **340** of the housing **105**. The cutting head assembly **145** includes an aperture **342** (FIGS. 5A-5D) aligned with the sight window **335** to continue the line of sight. The sight window **335** allows a user to properly align a pipe with the cutting wheel **170** and to observe the cutting process during use of the pipe cutter **100**. The sight window **335** may be formed of a variety of materials, including Plexiglas, as shown in the illustrated embodiment, or other transparent materials suitable for use in a power tool. Alternatively, the sight window **335** may include an opening with no covering.

Referring to FIG. 4, the pipe cutter **100** includes a light source **345**, such as an LED, to illuminate the cutting area **185**. The light source **345** is located within the forward portion **110** of the housing **105** and adjacent to the sight window **335**. The light source **345** is activated via a light switch (not shown). The light switch may be electrically coupled with or separate from the switch assembly **125** of the pipe cutter **100**. The light switch may be configured to remain activated at all times during the operation of the pipe cutter **100** or only for a certain period of time, such as for 5 or 10 minutes. Alterna-

tively, the light switch may be configured to be activated any time contact with a pipe is initiated by the cutting head assembly **145**.

Once the pipe is located in the over-center position within the pipe cutter **100**, the user may initiate the cutting process by activating the power supply **120** of the pipe cutter **100**. To activate the power supply **120**, the user moves the direction switch **127** into a forward position and engages the power switch **126**. Activation of the power supply **120** of the pipe cutter **100** causes the motor **130** to drive the drive assembly **140** and, in turn, rotate the cutting head assembly **145**.

Referring to FIG. 5A, the cutting head assembly **145** starts in an original home position in which the opening **173** of the head gear **165** is aligned with the opening **171** of the cutting head assembly **145** and the opening **106** of the housing **105**. As the drive assembly **140** initially rotates the cutting head assembly **145** in a forward direction about an axis **351**, the cam post **265** of the rotatable cam **250**, engages an element fixed within the housing **105**, such as a fixed cam or cam actuator **355** coupled to an interior of the forward portion **110** of the housing **105**. Upon engagement of the cam post **265** with the cam actuator **355**, the cam **250** rotates about an axis **352** such that the cam post **265** is forced toward an outer periphery **350** of the cutting head housing **146**, as shown in FIG. 5B. The cam **250** continues to rotate about the axis **352** until the cam lever **260** is aligned with the outer periphery **350** of the cutting head housing **146**, as shown in FIG. 5C, such that the cam **250** may move past the cam actuator **355**.

Rotation of the cam **250** facilitates loading of the springs **225, 226** of the cutting head assembly **145**. As shown in FIGS. 9A-9B, rotation of the cam **250** applies a load to the first and second springs **225, 226** by pulling the springs into the cutting area **185** and toward the lower carriage **180**. As the cam **250** rotates, the first cam surfaces **270** pull the first and second springs **225, 226** toward the lower carriage **180**. Loading of the springs **225, 226** applies a force to the cutting wheel axle **195**, and consequently, to the cutting wheel **170** and the upper carriage body **200**. Application of the load causes the cutting wheel axle **195** to translate within the slots **220** of the upper carriage body **200** and presses the cutting wheel **170** firmly against the pipe with force sufficient to cut the pipe.

Rotation of the cam **250** also locks the upper and lower carriages **175, 180** relative to each other in a position appropriate for the diameter of the inserted pipe. Prior to loading a pipe into the cutting area **185**, the upper and lower carriages **175, 180** are in an unlocked state and are independently movable relative to each other (FIGS. 7A-7C, 9A, and 10). When the cam **250** rotates as described above with respect to FIGS. 5A-5C, the second cam surface **275** of the cam shaft **255** raises a lifter element **360** located within a lower portion **361** of the upper carriage **175** (FIGS. 9B and 11). The cam **250** raises the lifter element **360** into contact with a locking plate **365**. The lifter element **360** includes a first portion that engages the cam shaft **255** and a second portion that engages the locking plate **365**. As shown in FIGS. 10-11, the locking plate **365** is substantially planar and includes an upper surface **366**, a lower surface **367**, a forward portion **368**, and a rearward portion **369**. An aperture **371** extends through the upper and lower surfaces **366, 367** and is configured for receiving the stem **395**.

When the carriages **175, 180** are in the unlocked state (FIGS. 9A, 10), the locking plate **365** is freely movable along a longitudinal axis of the stem **295**. As the cam shaft **255** rotates, the lifter element **360** moves relative to the stem **295** and pushes against the rearward portion **369** of the locking plate **365** thereby pivoting the locking plate **365** about the stem **295** and the forward portion **368** toward the lower car-

riage 180. The pivoting action moves the upper surface 366 of the locking plate 365 into engagement with one of the stem notches 300 (FIGS. 9B, 11). Each of the notches 300 corresponds to a different pipe size. In the illustrated embodiment, the notches 300 are configured for ASTM B88 standard pipe sizes. In another embodiment (not shown), the notches 300 may be configured for ASTM B88 standard pipe sizes as well as EMT pipe sizes. In a further embodiment (not shown), the notches on the stem 295 may be eliminated to accommodate for any pipe size. In such an embodiment, the locking plate 365 would engage with the stem 295 and hold the stem 295 in place via friction. Pivoting movement of the locking plate 365 also moves the forward portion 368 of the locking plate 365 into engagement with a rear surface 370 of the upper carriage body 200 (FIG. 11). Engagement of the locking plate 365 with the upper carriage 175 and the stem 295 locks the carriages 175, 180 relative to each other in a locked state. In the locked state, the carriages 175, 180 rotate as one unit, which prevents the inserted pipe from wobbling during rotation of the cutting head assembly 145 and reduces the risk of cutting imperfections.

As shown in FIGS. 5A-5D, the cutting head assembly 145 also includes a stop lever 375, coupled to an interior portion of the housing 105. The stop lever 375 includes a curved first side edge 380 proximate the cutting area 185 and an opposite second side edge 381. Side edge 380 allows continued rotation of the cutting head assembly 145 without interference by the lever 375 (FIG. 5C). A lower corner 385 of the stop lever 375, where the curved side 380 terminates, operates to terminate rotation of the cutting head assembly 145, remove the load on the first and second springs 225, 226, and unlock the upper and lower carriages 175, 180. The stop lever 375 is coupled to the housing 105 at a pivot point 376. The stop lever 375 is biased to a first position, toward the cutting area 185 (FIG. 5A-5D), by a biasing mechanism, such as a torsion spring (not shown). The travel path of the stop lever 375 is defined by a slot 377 in the stop lever 375 and a pin 378 coupled to an interior portion of the housing 105 and extending through the slot 377.

As the cutting head assembly 145 continues to rotate through as many revolutions as necessary to complete the cut, the cam lever 260 remains aligned with the outer periphery 350 of the cutting head housing 146 such that the cam post 265 does not impede the rotation of the cutting head assembly 145. When the cutting head assembly 145 has rotated nearly 360 degrees from its original position, the cam post 265 contacts the stop lever 375 (FIG. 5C). Upon contact between the cam post 265 and the stop lever 375, the force of the contact overcomes the force of the lever torsion spring (not shown) to move the stop lever 375 away from the cutting area 185 and to a second position, as shown in FIG. 5C. With the stop lever 375 in this second position, the cam post 265 continues to move freely along the side edge 380 of the stop lever 375.

The cutting head assembly 145 continues to rotate until the cutting operation is complete. In some embodiments, when a cutting operation is complete, the user activates the direction switch 127 to reverse the cutting head assembly 145 to the original "home" position (FIG. 5A) such that the pipe cutter 100 is ready to begin another cutting operation. As shown in FIG. 5D, during the rotation of the cutting head assembly 145 in the reverse direction, the cam post 265 engages the lower corner 385 of the stop lever 375. Upon engagement, cam 250 rotates until fully extended and back to the original home position shown in FIG. 5A, thereby releasing the load on the cutting springs 225, 226 and returning the upper and lower carriages 175, 180 to the unlocked state. Further rotation of

the cutting head assembly 145 in the reverse direction, causes the stop lever 375, which is now in the first position, to engage a stop boss 390 located on the cutting head housing 146. As the stop lever 375 engages the stop boss 390 and provides resistance to further rotation, the clutch 151 slips out of engagement with the bevel gear 153 and thereby terminates further rotation of the drive assembly 140 and the cutting head assembly 145. At this point, the cutting head assembly 145 is positioned in its original home position, with the upper and lower carriages 175, 180 in the unlocked state to release the cut pipe from the cutting area 185 and accept another pipe to be cut.

In one embodiment, the pipe cutter 100 is configured to detect when the cutting head assembly 145 has finished cutting a pipe. Completion of the cut is detected, in some embodiments, by monitoring current draw of the motor 130 as the pipe cutter 100 cuts a pipe. FIG. 22 shows the approximate current draw by the motor 130 as a function of time during a pipe cut operation. The current draw remains relatively low until the cutting wheel 170 engages the pipe and the upper and lower carriages 175, 180 are locked, as indicated by position 801. Engagement of the cutting wheel 170 with the pipe causes mechanical resistance between the pipe and the cutting wheel 170, whereby the motor 130 draws more current in order to rotate the cutting head assembly 145. When the cut is completed, as indicated by position 803, mechanical resistance between the cutting wheel 170 and the pipe is reduced. Therefore, the current needed to rotate the cutting head assembly 145 is also reduced.

By monitoring the amount of current draw, the control circuit 131 in this embodiment is able to detect the start and completion of the pipe cut operation. FIG. 23A illustrates a state diagram that is implemented by software in the programmable microcontroller of the control circuit 131. In some embodiments, the user only needs to press the power switch 126 (FIG. 2A) once and the pipe cutter automatically advances through the state diagram shown in FIG. 23A when state transitions are encountered. In other embodiments, the user holds the power switch 126 while the motor 130 and the cutting head assembly 145 move (i.e., while the pipe cut operation is being performed).

The pipe cutter 100 begins in an idle state 811. When the power switch 126 is pressed, the software program advances to a pre-cut state 813. FIG. 23B illustrates operations performed by the pipe cutter 100 while in the pre-cut state 813. Initially, the cutting head assembly 145 rotates (step 819). The cutting wheel 170 engages the pipe and the upper and lower carriages 175, 180 are locked in place (step 821). The current draw is monitored through circuitry connected to an analog-to-digital converter pin of the microcontroller. When the observed current draw exceeds threshold A (as shown in FIG. 22), the controller determines that the pipe cutter 100 has begun to cut the pipe and advances to a cutting state 815.

In some embodiments, the microcontroller is configured to return from the pre-cut state 813 to the idle state 811 if the observed current does not exceed threshold A after a preset time period (such as 1 second). This accounts for errors, such as a failure of the locking mechanism, or if the pipe cutter 100 is activated before the cutting head assembly 145 is placed in position around a pipe.

While in the cutting state 815, the pipe cutter 100 continues to rotate the cutting head assembly 145 until the current draw drops below threshold A, indicating that the pipe has been cut completely. The software program then advances to a post-cut state 817. In the post-cut state 817 (as illustrated in FIG. 23C), the upper and lower carriages 175, 180 are unlocked relative to each other (step 823), the cutting head assembly 145 is

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rotated to the home position (step 825), and the software program returns to the idle state 811.

In some embodiments, the pipe cutter 100 is able to detect when the cutting head assembly 145 reaches the home position, which triggers the advancement of the software program from the post-cut state 817 to the idle state 811. As described above, some embodiments include a drive assembly 140 with a clutch 151 (FIG. 3) that disengages when the cutting head assembly 145 returns to the home position by reverse rotation. Disengagement of the clutch 151 stops the rotation of the cutting head assembly 145. In some embodiments, the microcontroller begins rotating the motor 130 and the cutting head assembly 145 in the reverse direction during the post-cut state 817. The microcontroller then detects disengagement of the clutch 151, stops rotation of the motor 130, and advances the software program to the idle state 811. In other embodiments, the home position is detected by a position sensor, such as a Hall Effect sensor.

In some embodiments, the microcontroller automatically stops rotation of the motor 130 and the cutting head assembly 145 in the post-cut state 817. The user then manually operates the pipe cutter 100 until the cutting head assembly 145 returns to the home position. In other embodiments, the microcontroller automatically reverses direction of the motor 130 and the cutting head assembly 145 in the post-cut state 817. The user then releases the power switch 126 and stops rotation of the motor 130 when the cutting head assembly 145 returns to the home position.

The time required for cutting a pipe varies based upon at least a pipe diameter, a pipe thickness, or a pipe material. In the illustrated embodiment, the motor 130 of the pipe cutter 100 operates at between about 370 revolutions per minute (RPM) and about 390 RPM. The following chart provides examples of the average cut time (in seconds) and revolutions per cut for a variety of copper pipes that may be used with the pipe cutter.

Pipe Type	1/2" M	1/2" L	1/2" K	3/4" M	3/4" L	3/4" K	1" M	1" L	1" K
Average Cut Time	2.54	4.42	5.55	3.22	6.29	15.19	5.65	11.12	20.74
Revolutions Per Cut	12-16	21-28	27-36	15-20	30-40	74-98	27-36	54-72	101-134

Referring to FIG. 12, the pipe cutter 100 includes a fuel gauge 395 to assist a user in evaluating the remaining battery life. The fuel gauge 395 is located in an easily viewable region of the pipe cutter 100 on the housing 105. The fuel gauge 395 may be illuminated by one or more indicator lights, such as one or more light emitting diodes (LEDs). As shown in FIG. 12, the illustrated fuel gauge 395 displays four different indicators relating to four different degrees of battery life. For example, four lit LEDs indicate a 100% battery life remaining, three lit LEDs indicates 75% battery life remaining, two lit LEDs indicate 50% battery life remaining, one lit LED indicates 25% battery life, and one flashing or blinking LED indicates a battery life of 10% or less. In some embodiments, a flashing or blinking LED may indicate to the user that the battery pack 120 needs to be charged or replaced. The fuel gauge 395 is selectively activated by a switch 400, or may remain illuminated at all times during the operation of the pipe cutter 100.

FIG. 24 shows a graph illustrating approximate voltage of a rechargeable battery as a function of time (or battery life) during use. A battery with a nearly full charge has a relatively stable voltage. When the battery charge is nearly depleted, the

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voltage drops relatively quickly. The battery life remaining (or state of charge) can be evaluated by observing the voltage of the battery. In some embodiments, the voltage of the battery is monitored through circuitry connected to the analog-to-digital converter pin of the microcontroller.

In the illustrated embodiment, the microcontroller uses the observed state of charge to regulate operation of the pipe cutter 100. FIG. 24 shows three thresholds (B, C, and D), which are used to prevent damage to the pipe cutter 100 or the battery, and to prevent inconvenience to the user.

In some embodiments, it may be difficult to remove the pipe cutter 100 from a pipe if the battery life expires while the cutting head assembly 145 is in a use position (i.e., not in the home position) and the upper and lower carriages 175, 180 are locked in place. Threshold B is set higher than the anticipated amount of battery life needed to complete a pipe cut and return the cutting head assembly 145 to the home position. In various embodiments, threshold B can range from only slightly greater than the approximate state of charge needed to complete the operation once to more than ten times the approximate state of charge needed. A higher threshold B decreases the chance of the battery life expiring while cutting a pipe. The illustrated embodiment uses a 12V battery pack. Threshold B is set as 10.5V (point 831) which correlates to approximately 5% remaining of the maximum battery charge.

Although threshold B approximates the state of charge required to complete a pipe cut and return the cutting head assembly 145 to the home position, this approximation may not be accurate under certain conditions. For example, the actual state of charge required to cut an unusually thick or hard metal pipe may be higher than threshold B. Referring to FIG. 24, threshold C is greater than the approximate state of charge required to return the cutting head assembly 145 to the home position. If the state of charge falls below threshold C while pipe cutter 100 is cutting a pipe, the microcontroller terminates the cutting operation and returns the cutting head

assembly 145 to its home position. In the illustrated embodiment, threshold C is set at approximately 9.5V (point 833).

Some rechargeable batteries, such as lithium-ion batteries, may be permanently damaged if over-discharged. Referring to FIG. 24, threshold D is set to be higher than the charge level at which such an over-discharged condition occurs in the rechargeable battery. If the amount of remaining charge observed by the microcontroller falls below threshold D at any time, the microcontroller will stop all motor operation. In the illustrated embodiment, threshold D is set at approximately 8.6V (point 835). The voltage level associated with thresholds B, C, and D will differ depending on the requirements of the embodiment (for example, batteries with a higher or lower maximum voltage).

FIG. 25 illustrates a method of power management for the pipe cutter 100 utilizing the three thresholds shown in FIG. 24. In this embodiment, the motor 130 operates while the power switch 126 is depressed. When power switch 126 is released, the motor 130 stops. The pipe cutter 100 is idle (step 841) until the power switch 126 is pressed (step 843). The microcontroller then measures the state of charge on the battery pack (step 845) and compares the remaining battery

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charge to threshold B (step 847). If the state of charge does not exceed threshold B (as shown in FIG. 24 after point 831), the motor 130 does not start and the pipe cutter 100 remains idle (step 841).

If the state of charge is greater than threshold B, the pipe cut operation begins. The pipe cutter 100 engages the pipe with the cutting wheel 170 and locks the upper and lower carriages 175, 180 in place (step 849). The pipe cutter rotates the cutting head assembly 145 (step 851) while the power switch 126 is held down (step 852). If the switch is released (step 852), the rotation of the cutting head assembly 145 is stopped (step 856). In some embodiments, the user is able to resume rotation in either a forward or a reverse direction after releasing the power switch 126.

While the power switch 126 is held down or placed in the on position (step 852), the state of charge in the battery is repeatedly measured (step 853) and compared to the threshold C (step 855) by the microcontroller. If the state of charge falls below threshold C (as shown in FIG. 24 after point 833), the microcontroller stops rotation of the cutting head assembly 145 (step 856). The user then reverses rotation direction using direction switch 127 (step 857) and presses power switch 126 (step 858) to unlock the upper and lower carriages 175, 180 (step 859) and begin to rotate the cutting head assembly 145 to the home position (step 861).

As discussed above, rotation of the cutting head assembly 145 to the home position is performed without user intervention in some embodiments. In other embodiments, the user is able to rotate the cutting head assembly 145 to the home position manually. In some embodiments, when the amount of remaining charge falls below threshold C, the microcontroller prevents the motor 130 from operating until the direction of rotation is reversed using direction switch 127 (step 857). In other embodiments, the user is able to continue rotating in a forward direction by releasing and again depressing the power switch 126. In some situations, continuing to rotate the cutting head assembly 145 in the forward direction after the amount of remaining charge falls below threshold C increases the risk of battery failure while the upper and lower carriages 175, 180 are locked in place around a pipe. In other situations, the cutting head assembly 145 may require less battery power by continuing with a forward rotation than by reversing and returning to the home position—for example, if the cutting head assembly has almost completed a full rotation and has almost returned to the home position when the state of charge falls below threshold C.

The cutting head assembly 145 continues to rotate toward the home position (step 861) until the power switch 126 is released (step 862). While rotating toward the home position, the microcontroller continues to monitor the amount of remaining charge (step 863) and compare the amount to the threshold D (step 865). If the amount of remaining charge falls below the threshold D (as shown in FIG. 24 after point 835), the microcontroller stops the rotation of the cutting head assembly 145 (step 867) and returns to idle (step 841). Because the threshold D is lower than the threshold B, the pipe cutter will remain idle (in steps 841 through 847) until the battery is charged or replaced and the state of charge again exceeds the threshold B.

The sequence of operation illustrated in FIG. 25 can be modified for embodiments described above that detect when the pipe cut is completed, automatically reverse the rotation of the cutting head assembly 145, and detect when the cutting head assembly 145 returns to the home position. Furthermore, although the embodiment of FIG. 25 reacts to all three thresholds (B, C, & D), other embodiments may utilize one, two, or none of these thresholds.

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FIG. 13 illustrates another embodiment of a cutting head assembly 445. The cutting head assembly 445 is similar to and operates similarly to the cutting head assembly 145 shown in FIGS. 1-11; therefore, like structure will be identified by the same reference numerals. The cutting head assembly 445 includes one or more additional mechanisms configured to interact with the cam lever 260 and cam post 265 during rotation.

As shown in FIG. 13, when the cutting head assembly 445 begins to rotate, the cam lever 260 engages the cam actuator 355, as discussed above, and engages a movable lever 450. The movable lever 450 replaces the stop lever 375 of the previous embodiment. In the illustrated embodiment, the movable lever 450 is spring-biased away from the upper and lower carriages 175, 180. As the cam lever 260 moves into alignment with the cutting head assembly 445 (as discussed above with respect to FIGS. 5A-5B), the cam lever 260 rotates the movable lever 450 toward the upper carriage 175 until the cam lever 260 is able to move past the movable lever 450 and the cam actuator 355. With the cam lever 260 aligned with the cutting head assembly 445, the cutting head assembly 445 continues to rotate. When the cutting process is completed, a user moves the direction switch to a reverse mode to return the cutting head assembly 445 to the home position. As the cutting head assembly 145 moves in the reverse direction, the cam lever 260 engages a tip 455 of the movable lever 450. The engagement forces the movable lever 450 to rotate toward the upper carriage 175 and forces the cam lever 260, and consequently, the cam 250, to rotate out of alignment with the cutting head assembly. The rotation removes the load from the first and second springs 225, 226 and unlocks the upper and lower carriages 175, 180.

FIGS. 14-21 illustrate a pipe cutter 500 according to another embodiment of the invention. Similar to the previously described embodiments, the pipe cutter 500 receives power from a battery 505. The pipe cutter 500 includes a housing assembly 510 including a body 515 and a handle portion 520. The body 515 defines a forward portion 522 that supports a cutting head assembly 525. The body 515 of the pipe cutter 500 also includes a motor 530. The operation of the battery powered motor is implemented in a similar fashion to that of the previous embodiments, including a control circuit 532.

As shown in FIG. 15, pipe cutter 500 includes a drive assembly 535, such as the drive assembly 140 described with respect to FIG. 2A. The drive assembly 535 includes a drive gear 540, a first idler gear 545, a second idler gear 550, and a head gear 555. Similar to previously discussed embodiments, the drive assembly 535 operates to rotate a cutting head assembly 525, which in turn, causes a cutting carriage 560 to facilitate the cutting operation.

A cutting head assembly 525 and portions of the cutting head assembly 525 are shown in FIGS. 16-21. In these embodiments, the cutting head assembly 525 is configured to receive and cut pipes of various sizes, thicknesses and materials. For example, in the illustrated embodiment, the cutting head assembly 525 accommodates 1/2" diameter pipe (designated with reference number 565), 3/4" diameter pipe (designated with reference number 570) and 1" diameter pipe (designated with reference number 575). In other embodiments, the cutting head assembly 525 may be configured to receive and cut a fewer or greater number of pipe sizes than shown and described and/or different pipe sizes and thicknesses than shown and described.

As shown in FIG. 16, the cutting head assembly 525 includes a cutting head 600 having a first area 601 and a second area 603. The cutting head 600 defines an opening 602

in which to receive a pipe or workpiece for cutting. The cutting head 600 also defines a cutting area 604 in which to position the pipe for cutting. As shown in FIG. 16, the cutting area 604 is generally circular and has a center point 606. The pipe is positioned within the cutting area 604, such that a longitudinal axis of the pipe is positioned roughly within the center point 606 of the cutting area 604. As shown in FIG. 16, the first area 601 of the cutting head 600 is positioned on one side of the center point 606 and the second area 603 of the cutting head 600 is positioned on the other side of the center point 606 across from the first area 601. As discussed below, the cutting head 600 rotates around the pipe roughly about the center point 606 during the cutting operation.

In the illustrated embodiment, the cutting head assembly 525 also includes a blade or cutting wheel 605 mounted to a cutting wheel carriage 610. Portions of both the cutting wheel 605 and the cutting wheel carriage 610 are contained within and supported by the cutting head 600. As shown in FIG. 16, the cutting wheel carriage 610 includes a cutting wheel mounting portion 612, a supporting leg portion 613 coupled to and extending from the cutting wheel mounting portion 612 and an arm portion 614 coupled to and extending from the supporting leg portion 613. A portion of the cutting wheel 605 protrudes from the first area 601 of the cutting head 600 and the cutting wheel carriage 610 into the cutting area 604.

The cutting head assembly 525 may also include a roller assembly 615. As shown in FIG. 16, at least a portion of the roller assembly 615 is contained within and supported by the cutting head 600. The roller assembly 615 also includes a portion which protrudes into the cutting area 604. The cutting area 604 is positioned between the roller assembly 615 and the cutting wheel 605 and wheel carriage 610. During operation, the pipe to be cut is centered within the cutting area 604 by the roller assembly 615, as discussed below.

The roller assembly may include one or more rollers mounted on a roller carriage 620. In the illustrated embodiment, the roller assembly 615 includes a first roller 625 and a second roller 630 mounted on the roller carriage 620.

The roller assembly 615 may also include an adjustment plate 640. The distance that the roller assembly 615 protrudes into the cutting area 604 may be adjusted via the adjustment plate 640. As shown in FIG. 20, the adjustment plate 640 includes three (3) fittings: a first fitting 650, a second fitting 655 and a third fitting 660. The roller carriage 620 includes an aperture 665 for receiving a set screw. The set screw couples the roller carriage 620 to the adjustment plate 640 through one of the three fittings 650, 655, 660. In the illustrated embodiment, the fittings 650, 655, 660 correspond to the three different sizes of pipe the pipe cutter 500 may cut. For example, the roller assembly 615 may be adjusted to accommodate the 1/2" diameter pipe by coupling the roller carriage 620 to the adjustment plate 640 through the first fitting 650. Also as an example, the roller assembly 615 may be adjusted to accommodate the 3/4" diameter pipe by coupling the roller carriage 620 to the adjustment plate 640 through the second fitting 655. The roller assembly 615 may be further adjusted to accommodate the 1" diameter pipe by coupling the roller carriage 620 to the adjustment plate 640 through the third fitting 660.

As shown in FIGS. 16-21, the cutting head assembly 525 further includes a timing gear 675, a worm screw 680, an advancing gear 685, a threaded cutting screw 690, and a pawl 695. In the illustrated embodiment, the timing gear 675 is fixed to the housing 510 and does not rotate with the cutting head 600. The timing gear 675 includes a non-threaded por-

tion 676 and a threaded portion 677. Only the threaded portion 677 of the timing gear 675 engages with the worm screw 680, as shown in FIG. 18.

The worm screw 680 is mounted to the cutting head 600 and engages with both the threaded portion 677 of the timing gear 675 and the advancing gear 685. The advancing gear 685 is coupled to the end of the threaded cutting screw 690. Thus, the threaded cutting screw 690 rotates or spins with the advancing gear 685. The pawl 695 is threadedly engaged with the threaded cutting screw 690 and moves up and down the screw 690 depending on the direction of rotation of the cutting screw 690 and advancing gear 685.

The pawl 695 may be further coupled to the cutting head carriage 610 via a connection pin 696 (FIG. 20). As shown in FIG. 20, the pawl 695 pivots about the connection pin 696 from a closed or engaged position (FIG. 16) and an open or disengaged position (FIG. 19). In the closed position, the pawl 695 is threadedly engaged with the threaded cutting screw 690. In the open position, the pawl 695 is no longer threadedly engaged with the threaded cutting screw 690. As shown in FIG. 19, the pawl includes a threaded portion 697 which engages with the screw 690. When the pawl 695 moves with respect to the screw 690 (as will be discussed below), the threads bias the pawl 695 into the closed position. Also, as shown in FIG. 19, the pawl 695 includes a pawl pin 698 extending outwardly from the pawl 695.

As shown in FIGS. 16-21, the cutting head assembly 525 further includes a release 700, a trip lever 705, a trip frame 710 and a spring 720. The trip frame 710 is a metal frame supported by the housing 510. The trip frame 710 does not rotate with the cutting head 600 during operation. The trip lever 705 is mounted on the trip frame 710 and is biased toward a catch or stop surface 730 of the trip frame 710 via a trip spring.

As shown in FIGS. 18 and 21, the release 700 includes a pin 740 that extends through a pin opening 745 defined by the cutting head 600. The release 700, and thus the pin 740, is biased toward the cutting area 604 of the cutter 500 by a spring. The release 700 includes a slot 750 which receives the pawl pin 698 of the pawl 695. As the pawl 695 moves up and down the threaded cutting screw 690, the pawl pin 698 slides up and down the slot 750 of the release 700.

The spring 720 is a light spring which applies a smaller force to the cutting wheel carriage 610 when the pawl 695 is disengaged with the threaded cutting screw 690. When the pawl 695 is disengaged, the cutting wheel carriage 610 is free to move along the threaded cutting screw 690. However, the force applied by the spring 720 biases the carriage 610, and thus the cutting wheel 605, downward. In the illustrated embodiment, the force of the pipe, when inserted into the cutting area 604, overcomes the force exerted by the spring 720. When the pipe is inserted, the pipe forces the cutting wheel 605 upward, which forces the cutting wheel carriage 610 to move up the threaded cutting screw 690 and "snap" the pawl 695 into engagement with the screw 690.

Operation of the pipe cutter 500 will be described with respect to FIGS. 15-21. First, the user selects the pipe to be cut and positions the pipe within the cutting area 604. As discussed above, when the pipe is inserted into the cutting area 604, the pipe pushes the cutting wheel 605 (and thus the cutting wheel carriage 610) upward and snaps the pawl 695 into engagement. Based on the diameter of the pipe, the user adjusts the roller carriage 620 to the appropriate height, such that the pipe rests on the first and second rollers 625 and 630.

When the user activates the ON position of a trigger from the OFF position, the motor 530 is energized by a battery 505 to drive the drive gear 540 in a forward direction. The drive

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gear **540** and the remainder of the drive assembly operate in the same or similar manner to the drive assembly discussed in previous embodiments.

Referring to FIGS. **16-17**, the cutting head **600** now rotates in forward direction and moves the cutting wheel **605** around the circumference of the pipe. As the cutting head **600** rotates and the cutting wheel **605** cuts the pipe, the worm screw **680** engages with the threaded portion **677** of the timing gear **675** and rotates clockwise. When the worm screw **680** passes the threaded portion **677** of the timing gear **675**, the worm screw **680** is no longer in engagement with the timing gear **675** and stops rotation. Accordingly, during one revolution of the cutting head **600**, the timing gear **675** only engages with the worm screw **680** for a portion of that revolution and only advances the screw **680** a few revolutions.

The clockwise rotation of the worm screw **680** drives the advancing gear **685** in a counter-clockwise manner, but again, only when the worm screw **680** is engaged with the threaded portion **677**. Every time the advancing gear **685**, and in turn the cutting screw **690**, is driven in the counter-clockwise manner, the threaded cutting screw **690** forces the pawl **695** to move down the threaded cutting screw **690**. This in turn forces the cutting wheel carriage **610** to move downward toward the cutting area **604** at a certain rate. In the illustrated embodiment, this assembly is configured such that the cutting wheel carriage **610** (and thus the cutting wheel **605**) advances 0.004" per revolution of the cutting head **600**. In other embodiments, the feed rate of the cutting wheel **605** may be greater than or less than the feed rate shown and described.

Also, as the cutting head **600** rotates clockwise, a ridge **800** coupled to the outside surface of the cutting head **600** engages with the trip lever **705** and overcomes the force of the trip spring to bias the trip lever **705** away from the cutting area **604**. When the end portion **805** of the ridge **800** passes, the trip spring biases the trip level **705** back against the catch **730** of the trip frame **710** until the next revolution.

During each revolution of the cutting head **600**, the cutting wheel **605** advances downward toward the cutting area **604** at the feed rate described above. Once the cutting wheel **605** has completed the cut, the user selects the reverse position of the trigger. This reverses the direction of the motor **530** and the cutting head **600** is driven in a counter-clockwise manner as shown in FIG. **16**.

Referring to FIG. **16**, as the cutting head **600** rotates in a counter-clockwise manner, the pin **740** of the release **700** is forced away from the cutting area **604** by the trip lever **705**. The release **700**, in turn, forces the pawl **695** to disengage with threaded cutting screw **690** and the cutting wheel carriage **610** is biased back down in the home position, ready for the next cut.

In the illustrated embodiment, for example, the pipe cutter **500** with a feed rate of 0.004" per revolution cuts a ¾" diameter type pipe in eight (8) revolutions. At 620 revolutions per minute, the cut takes approximately four (4) seconds. In other embodiments, the feed rate and speed of the cutter **500** may be optimized for certain pipe sizes, types and/or materials.

Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of one or more independent aspects of the invention as described.

What is claimed is:

1. A power tool configured to cut an object, comprising:
a motor configured to drive an operation;
a cutting assembly for cutting the object, the cutting assembly including a blade and a body portion positioned

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opposite the blade, the blade and the body portion defining a cutting area for receiving the object;

a controller configured to monitor a state of charge of a battery connected to the motor,

compare the state of charge to a predetermined first threshold, the first threshold being greater than the state of charge needed by the motor to complete the operation, and the first threshold being greater than a second threshold, the second threshold related to the state of charge at which an over-discharged condition occurs in the battery,

wherein the operation includes performing at least a portion of a cutting action and returning the cutting assembly to a starting position, and

prevent the motor from driving the operation when the state of charge is less than or equal to the first threshold.

2. The power tool of claim **1**, wherein the first threshold is approximately equal to the state of charge required to drive the operation ten times.

3. The power tool of claim **1**, wherein the first threshold is approximately equal to 5% of a maximum state of charge of the battery.

4. The power tool of claim **1**, wherein the controller is further configured to

store a second threshold that is greater than a state of charge indicative of an overdischarged state that causes damage to the battery, and

stop the motor when the state of charge is less than or equal to the second threshold.

5. The power tool of claim **1**, further comprising a removable battery pack, and wherein the removable battery pack includes the battery.

6. The power tool of claim **1**, wherein the cutting assembly is operated by the motor.

7. The power tool of claim **6**, wherein the operation driven by the motor includes rotating the cutting assembly around a circumference of the object in a first direction.

8. The power tool of claim **7**, wherein the controller is further configured to

store a third threshold that is greater than the state of charge required to return the cutting assembly in a second direction to a home position,

stop rotation of the cutting assembly in the first direction when the state of charge is less than or equal to the third threshold, and

allow the motor to rotate the cutting assembly in the second direction when the state of charge is less than or equal to the third threshold.

9. The power tool of claim **7**, wherein the controller is further configured to

control the operation of the motor and, thereby, control the operation of the cutting assembly, and

detect when the cutting assembly is in a home position.

10. The power tool of claim **9**, wherein the controller is further configured to

store a third threshold that is greater than the state of charge required to return the cutting assembly to the home position,

interrupt and prevent regular operation of the motor when the state of charge is less than the third threshold, and

rotate the cutting assembly to the home position when the state of charge is less than the third threshold.

11. The power tool of claim **7**, wherein the controller is further configured to detect when the cutting assembly has finished cutting the object.

12. The power tool of claim 11, wherein the controller is configured to detect when the cutting assembly has finished cutting the object by

detecting a current draw of the motor, and
 comparing the current draw of the motor to a fourth thresh- 5
 old, wherein the fourth threshold is lower than the cur-
 rent draw when the motor is running and the cutting
 assembly is cutting the object, and the fourth threshold is
 greater than the current draw when the motor is running
 and the cutting assembly is not cutting the object. 10

13. The power tool of claim 11, wherein the controller is configured to automatically rotate the cutting assembly to a home position when the controller detects that the cutting assembly has finished cutting the object.

14. The power tool of claim 1, wherein 15
 the operation includes the cutting action followed by a
 second action, and
 the controller is further configured to
 store a third threshold that is greater than the state of
 charge required to drive the second action, 20
 prevent performance of the cutting action when the state
 of charge is less than the third threshold, and
 allow the motor to drive the second action when the state
 of charge is greater than the third threshold.

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